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MARSHA J. KWOLEK
An Analysis of Performance Measurement Systems in the Air Force Logistics Command's Aircraft Repair Depots
(Under the direction of JAMES F. COX, III)

This dissertation explores the goals and objectives, competitive edges, performance criteria, and system constraints of a selected group of depot maintenance organizations in the Air Force Logistics Command's (AFLC's) aircraft repair depots. Through interviews of managers at the directorate, division, branch, and first-line supervision levels, the selected organizations were asked to identify the competitive edges on which they compete. The organizations were then studied at the directorate, division, and branch levels to determine how performance on the critical competitive edges is measured and to identify the constraints that prevent the depots from achieving their objectives. The results of this research were: (1) The development of guidelines concerning AFLC goals and depot objectives, competitive edges, performance criteria, and system constraints; and (2) A prescriptive depot maintenance performance model showing the desired relationships among proposed depot objectives, critical competitive edges identified by AFLC managers (quality, cost, and delivery), proposed performance criteria, and current system constraints. Due to the exploratory nature of this research, a case study methodology was employed.

INDEX WORDS: Aircraft Maintenance, Competitive Edges, Depot Maintenance, Performance Measurement Systems, System Constraints, Theory of Constraints

AN ANALYSIS OF PERFORMANCE MEASUREMENT SYSTEMS IN THE AIR FORCE LOGISTICS COMMAND'S AIRCRAFT REPAIR DEPOTS

by

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M.B.A., Golden Gate University, 1982

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AN ANALYSIS OF PERFORMANCE MEASUREMENT SYSTEMS IN THE AIR FORCE LOGISTICS COMMAND'S AIRCRAFT REPAIR DEPOTS

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Several other individuals made important contributions to this research. Lt Colonel Richard Moore, an assistant professor at the Air Force Institute of Technology, provided

invaluable assistance with the construction of the effect-cause-effect (ECE) diagrams. Ms. Jonna Hamrick typed all the ECE diagrams, tables, and many of the figures, and Ms. Wanda Arnold formatted the final document.

I would also like to thank the many managers and supervisors at the Warner Robins, Ogden, and Sacramento Air Logistics Centers (ALCs) who gave freely of their time to explain their operations. While everyone at these three ALCs was very helpful, three managers in key positions were especially generous with their time. Mr. George Falldine, the deputy director of the Avionics Directorate at Warner Robins ALC, expounded on the workings of the Department of Defense (DOD) budgeting process at length. Colonel Robert Pape, the Landing Gear Division chief at Ogden ALC's Commodities Directorate, acted as the project officer for the Ogden ALC site visit and discussed his division in detail. Colonel Donald Story, the Production Division chief for Sacramento ALC's Aircraft Management Directorate, explicated on DOD personnel policies and their impact on his operation.

Finally, credit must also be given to the Air Force Institute of Technology for sponsoring my doctoral program. I owe the Air Force a great deal for affording me this educational opportunity.

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CHAPTER I

INTRODUCTION AND PROBLEM STATEMENT

Dissertation Summary

With the recent reductions in defense budgets, personnel, and weapon systems, the Air Force Logistics Command's commanders and supervisors recognize that the command must operate like a business and become more competitive. These managers also realize that, if AFLC's aircraft repair depots are to compete successfully with other military depots and with private contractors, the AFLC performance measurement system must be revised. The purpose of this dissertation was to study the performance measurement systems of the Air Force Logistics Command's (AFLC's) aircraft repair depots in order to develop a prescriptive model of performance criteria that are appropriate for these depots. Organizations responsible for the depot maintenance of six different types of aircraft at three separate Air Logistics Centers (ALCs) - Warner Robins ALC (WR-ALC), Ogden ALC (OO-ALC), and Sacramento ALC (SM-ALC) - were examined using a case study methodology. Each case looked at the depot maintenance process for a particular type of aircraft - C-130, C-141, F-4, F-16, A-10, or F-111. For each of the six cases, descriptions of organizational structure and workload, current performance

criteria, and system constraints were provided. An analysis of how managers at various levels assess the importance of employing certain competitive advantages, or edges, as the basis for an AFLC performance measurement system was also given.

The end result of this research was the development of a set of guidelines concerning AFLC goals and depot objectives, competitive edges, performance criteria, and system constraints. A prescriptive model for AFLC depot maintenance performance was also created using system components suggested by Cox and Blackstone (1990) and by Dixon, Nanni, and Vollmann (1990). For an organization to effectively accomplish its goals, it must know where its primary constraints are for each competitive advantage, or edge, that customers consider to be important. In addition, strategic objectives and performance criteria should be established for each critical competitive edge (Cox & Blackstone, 1990). Therefore, the system components selected for the prescriptive model were strategy (AFLC goals and depot objectives), competitive edges, performance criteria, and system constraints. Additionally, several effect-cause-effect (ECE) diagrams were constructed to aid practitioners in identifying problems and constraints in the depot maintenance process.

Conceptual Framework

AFLC Goals and Depot Objectives

Figure I-1 outlines the variables of primary interest in this study, the elements constituting each variable, and the desirable relationships among the variables. The arrows in Figure I-1 depict these desired, but not always actual, relationships. The command goals and the objectives of its depots (ALCs) form the essence of AFLC's strategy. This strategy determines the particular competitive edges emphasized by the command. However, constraints present in the depot maintenance system impact both the command strategy and the competitive edges. Ideally, the AFLC performance measurement systems should support the AFLC strategy. In the final analysis, the four primary variables interact in varying degrees to influence the nature of depot maintenance performance.

For this dissertation, strategy is defined as "the plan that integrates an organization's major goals, policies, and action sequences into a cohesive whole" (Quinn, Mintzberg, & James, 1988, p. 3). The elements of strategy are defined as follows:

Organizational goals: Desired future states which the organization seeks to achieve. The goals are broad, general guidelines to thinking which provide levels of attainment that are relatively timeless (Harvey, 1988, p. 33). For this research, the term goals always

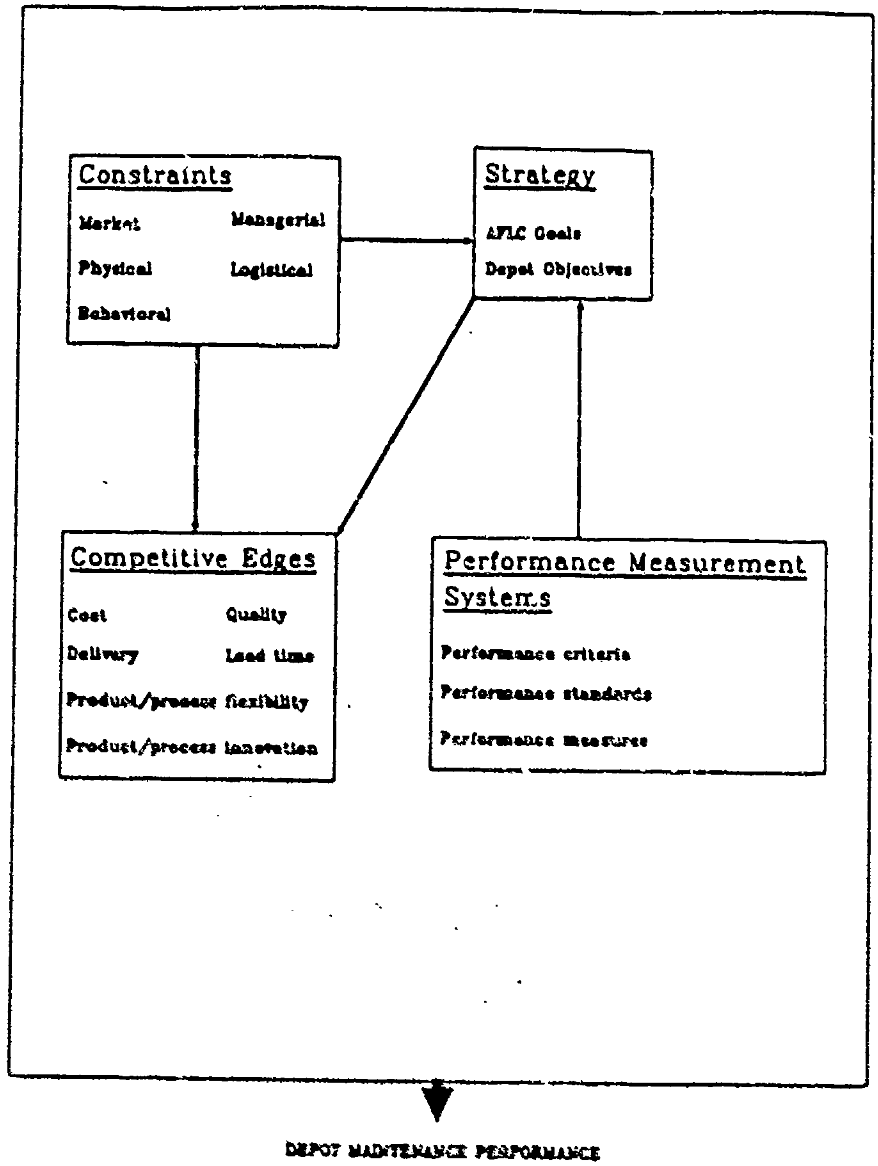


Figure I-1. Conceptual Framework for AFLC Performance Measurement

refers to the desired results that a command (AFLC) seeks to achieve.

Organizational objectives: Statements that help guide the activities of groups and members toward the overall goals. Objectives, which are more specific and timebound than goals, are time-limited, measurable, and quantifiable (Harvey, 1988, pp. 33-34). For this study, the term objectives was used to specify the measurable targets that a depot or one of its subordinate units seeks to achieve.

Competitive Edges

Competitive edges are the critical success factors by which an organization competes, such as cost, quality, and due date performance. Cox and Blackstone (1990, p. 5) define a competitive edge as "any element on which an organization can attain a competitive advantage." They point out that an organization can compete on nine competitive edges: price (cost), quality, lead time, due date performance (delivery), product flexibility, process flexibility, field service, innovation, and product introduction responsiveness (Cox & Blackstone, 1990, p. 5). Definitions for the six competitive edges addressed in this study are as follows:

Cost: From the viewpoint of AFLC's customers, cost refers to price. From the standpoint of AFLC depot maintenance operations, however, cost refers to money spent turning inventory into throughput and also

includes waste, any expense that does not contribute to converting inventory into throughput (Goldratt & Fox, 1988, pp. 4, 13, 14). Waste reduction, or resource saving, encompasses eliminating nonvalue-added activities and unnecessary equipment, material, time, and space (Hall, Johnson, & Turney, 1991, p. 31).

Lead time: A span of time required to perform an activity. In a logistics context, the time between recognition of the need for an order and the receipt of goods (Wallace & Dougherty, 1987, p. 16).

Quality: Conformance to requirements or fitness for use (Fogarty, Blackstone, & Hoffmann, 1991, p. 618).

Delivery: Consistently performing at the time scheduled or promised. On-time delivery is the result of dependability (Hall, Johnson, & Turney, 1991, p. 31). For this study, delivery was synonymous with due date performance.

Flexibility: Responsiveness to change, or the reduction of lead time to make any significant change, such as changes in product design (Hall, Johnson, & Turney, 1991, p.32).

Innovation: Origination of useful new practices, or the successful introduction of new technology or service to a market (Hall, Johnson, & Turney, 1991, p. 32).

Performance Criteria

According to Cox and Blackstone (1990), strategic objectives and a performance measurement system consisting of performance criteria, standards, and actual measures should be established for each competitive edge deemed important by customers. Similarly, Dixon et al. (1990) observe that performance measurement systems should be supportive of a business's goals, objectives, critical success factors, and action programs, such as Total Quality Management (TQM). For this study, a performance measurement system is defined as "a systematic way of evaluating the inputs (raw material, equipment, facility, employee, etc.), outputs (end item), transformation, and productivity in a manufacturing or nonmanufacturing operation. The system includes performance criteria, standards, and measures" (Crawford, Cox, & Blackstone, 1988, p. 10). The system's elements are defined as follows:

Performance criterion: The relative element used to evaluate macro, micro, long-term, short-term, flow, static, functional, and overall system performance (Crawford, Cox, & Blackstone, 1988, p. 11). Parts per million is an example of a criterion used to measure quality defects.

Performance standard: The accepted, satisfactory level of performance (Crawford, Cox, & Blackstone, 1988, p. 11). A standard for quality defects could be two parts per million.

<u>Performance measure</u>: The actual value of the performance criterion (Crawford, Cox, & Blackstone, 1988, p. 11). The actual measure of quality defects might be five parts per million.

Because this study examined just one element of AFLC's performance measurement system, performance criteria, only this element was included in the depot maintenance performance model presented in Chapter VI. Also, throughout the dissertation the terms performance criteria, performance measures, and management indicators are used interchangeably. Performance measures is the term commonly employed by many researchers and practitioners to denote elements used to evaluate system performance. On the other hand, the AFLC practitioners encountered in this study typically used the term management indicators to refer to this same concept. Therefore, while performance criteria is actually the proper terminology, widely accepted usage dictated the inclusion of the other two terms.

System Constraints

For this dissertation, a constraint is defined as "anything that limits the system from achieving higher performance versus its goal" (Goldratt, 1989, p. 1). The following categories of constraints were employed in this study:

<u>Market Constraint</u>: Exists when the market demand for a particular product is less than the system's ability to fulfill market demand (Goldratt, 1989, p. 2).

Physical Constraint: Any constraint that is inherent in an organization's physical system, which is represented by its products-processes relationships and the layout of its facilities (Cox & Blackstone, 1990, p. 18).

Logistical Constraint: Any constraint that is inherent in the manufacturing planning and control system used by the firm (Umble & Srikanth, 1990, pp. 4-5). For this research, constraints related to an organization's management information and performance measurement systems were also placed in this category.

Managerial Constraint: Management strategies and policies that adversely affect all manufacturing-related decisions (Umble & Srikanth, 1990, pp. 4-5). For this research, this category included all local (depot level and below), AFLC, and DOD policies and procedures.

Behavioral Constraint: Any constraint related to the attitudes and behaviors exhibited by the workforce. Examples are the practice of "cherry-picking" and the "keep busy" attitude often displayed by supervisors (Umble & Srikanth, 1990, pp. 4-6).

These categories are neither mutually exclusive nor all inclusive. Certain constraints, such as operating by local efficiencies, could be placed in any one or all of the latter three categories. Other types of constraints not listed above, like material constraints and capacity

constraints, typically result from managerial policies or constraints in the logistical system. Therefore, in this study, material and capacity constraints were discussed in conjunction with either logistical or managerial constraints and were included in these categories.

Research Questions

Adam and Swamidass (1989) argue that empirical investigations of the effect of the manufacturing strategy content variables of cost, quality, delivery, flexibility, and technology-process on business performance are needed in manufacturing strategy content research. This observation, coupled with the lack of empirical research on performance measurement systems in nonprofit and military organizations, suggested that an opportunity existed for developing new theory. To focus the theory development, the following research questions were addressed in this study:

(1) Is there congruence between the goals of the Air Force Logistics Command (AFLC) and the depot-level and directorate-level objectives of its aircraft repair depots?

(2) Do managers at the directorate, division, branch, and first-line supervision levels agree on the ranking of the criticality of the competitive edges for accomplishing depot maintenance?

(3) Do performance criteria used at the directorate, division, and branch levels support the accomplishment of AFLC goals and directorate and depot objectives? If not,

what are some criteria that would better support these organizations' objectives?

(4) What types of constraints exist in these depots, and how do these constraints impact depot performance?

Importance of Research

Research Justification

Over the past decade American manufacturers shifted from a manager-centered to a customer-centered philosophy, but changes in performance measurement systems lagged behind this shift (Hall et al., 1991). As a result, performance measurement has proved to be a substantial barrier in the implementation of programs that focus on continuous improvement, such as Just-in-Time (JIT) and TQM (Dixon et al., 1990; Hall et al., 1991; Kaplan, 1990). Consequently, academicians and practitioners are realizing the importance of designing new performance measurement systems that support ongoing improvement and an organization's efforts to compete more effectively in today's global market.

With the recent defense budget reductions and plans to drawdown military equipment and personnel, military and government organizations also are becoming aware that their performance measurement systems are outmoded. Current defense depot maintenance performance measures focus on capacity and utilization. AFLC managers realize that the AFLC performance measurement system must be changed for the command to be able to compete successfully with the depots of other military services and with commercial repair

sources. A recent proposal for consolidating Department of Defense (DOD) depot maintenance prompted the Assistant Secretary of Defense to task the Defense Depot Maintenance Council (DDMC) to develop a performance measurement system for all military services that assesses "all depots' effectiveness, efficiency, productivity, and quality", promotes "continuous improvement of depot processes", and reflects "the results of team-designed Total Quality Management concepts" (Defense Depot Maintenance Council, September 10, 1990, p. 13).

The DDMC performance measures created and proposed in 1991 have now been implemented in AFLC and other DOD depot maintenance organizations. However, since the time that the DDMC was tasked to develop these measures, the product directorate reorganization has occurred in AFLC and a number of key AFLC managers have been educated in the Theory of Constraints (TOC). As a result, AFLC's top management is concerned that the DDMC performance measures will not adequately support AFLC goals and depot maintenance objectives. Therefore, an AFLC headquarters team is currently considering what measures, other than the DDMC measures, could be used by the command for internal reporting and assessment purposes.

Importance to Practitioners

This dissertation addressed a research need identified by AFLC and ALC commanders and key managers. By analyzing data across case studies, differences in performance

measurement systems and common constraints to AFLC depot maintenance performance were identified. Hopefully, such identification will improve communication among the various AFLC depots concerning the improvement of performance measurement and the elimination of system constraints. Thus, one of the aims of the prescriptive model was to aid depot practitioners in selecting appropriate performance criteria, or management indicators, at the division, directorate, and depot levels. The model should also make these practitioners more aware of the constraints that exist in their organizations. Constraint identification focuses the improvement process and is a prerequisite for changing performance measurement systems. "As performance improves, new measures and new controls are appropriate" (Dixon et al., 1990, p. 30).

This research should also have implications for other organizations in the depot maintenance supply-customer chain, such as base maintenance units and DOD contractors. Findings concerning system constraints and appropriate performance criteria should have direct application for some of the operations in these organizations.

Importance to Researchers

This dissertation can assist researchers in understanding the relationships between an organization's strategic goals and objectives and the performance measurement systems used at the strategic and operational levels. It can also aid in understanding how identifying

and managing a system's constraints can be used to focus the improvement process. In addition, because this dissertation was concerned with the congruency between performance criteria and strategic objectives in a nonprofit organization not involved in traditional manufacturing activities, it provides empirical research in two areas where there is currently very little. Of the performance measurement publications reviewed by this researcher, only 19 articles and seven books discussed linkages between functional and business level performance measures in manufacturing firms. Furthermore, only three studies in the military literature addressed the need for performance criteria at all levels to support command goals and organizational objectives.

The prescriptive model of performance criteria and its associated set of guidelines can be used as a basis for future research in performance measurement and for determining the applicability of the TOC philosophy to nonprofit organizations. To test the model and verify its usefulness, additional case studies may be required. The pre-visit questionnaires and surveys will need to be given to a larger sample of AFLC managers. Also, expansion of the sample to include managers from the depots of all military services would greatly enhance theory generalizability.

Limitations of the Study

Eisenhardt (1989) points out two key weaknesses of employing case studies to build theory. First, due to the inductive approach used to develop theory, a narrow theory that describes a very specific phenomenon may result. The theorist may be unable to generalize the theory to other phenomena or situations. Secondly, the theory derived from the empirical evidence of case studies may be overly complex and lack the simplicity of an overall perspective. In addition, the scope of this research was limited to theory development. Theory testing requires further research.

The following additional limitations of this research relate to the scope of the study and the time required to conduct it:

(1) The research was limited to the organizations identified by key directorate presidents as being critical for supporting depot maintenance of a particular aircraft type. Of the many divisions and branches which support the repair of these aircraft, only a few selected divisions and branches in two or three directorates at an ALC were examined. Other facilities responsible for depot repair of these aircraft, such as other ALCs, overseas depots, and contractors, were not included in the case studies.

(2) Case information and analysis conclusions were based on data collected at a particular point in time. Because of the continual organizational realignments and numerous changes ongoing in DOD and AFLC, certain

information and conclusions may no longer be valid by the time this dissertation is published. An example of reorganization pertinent to this study is the July 1, 1992 merger of the Air Force Logistics Command and the Air Force Systems Command into one unified command, the Air Force Materiel Command.

Organization of the Dissertation

Chapter I describes the research area, the importance of the topic to researchers and practitioners, and limitations of the study. Chapter II provides a critical evaluation of the relevant academic and military performance measurement system literature. A detailed description of the research methodology is given in Chapter III. Chapter IV contains six case studies. Chapter V provides an analysis of the case study data. Finally, Chapter VI consists of the prescriptive performance measurement model and its associated guidelines, as well as the dissertation summary, dissertation conclusions, and suggestions for further research.

CHAPTER II

REVIEW AND CRITIQUE OF RELEVANT LITERATURE

Performance Measurement Literature

Lockamy (1991) and Crawford (1988) each reviewed over 200 articles and books pertaining to performance measurement. Fifty of these publications and 20 additional academic books and articles relevant to the research questions addressed in this study are included in this literature review. The purpose of this literature review was to build on the previous work of Lockamy and Crawford as well as examine the military literature on performance measurement. The primary sources for the 60 military publications included in this review were Government Accounting Office (GAO) reports from January, 1988 through September, 1990, Air Force Magazine articles from January, 1988 through March, 1991, Air Force Journal of Logistics articles from Spring, 1989 through Summer, 1991, and publications listed in the 1981 through 1990 editions of the Annual DOD Bibliography of Logistics Studies and Related Documents. The academic and military performance measurement literature was classified into five categories related to the research questions in this study. The first three categories - productivity measurement of a business unit, performance measurement of functional areas, and

performance measurement linkages between operational and strategic levels - are related to the first and third research questions. The publications categorized under competitive edges and constraints relate to the second and fourth research questions.

Two findings related to the academic and military performance measurement literature were revealed by this literature survey. First, the survey substantiated the findings of Lockamy (1991) on the paucity of academic publications concerning performance measurement linkages between operational and strategic levels. Twenty-six of the 70 articles and books reviewed in the academic performance measurement literature included discussions of linkages between plant and business level performance measurement systems. However, only nine of these publications addressed the linkage issue in detail. Twenty of the academic publications reviewed focused on performance measures for various functional areas, while 17 percent (12 publications) concentrated on productivity measurement of a business unit.

Secondly, the survey revealed an even greater scarcity of writings on performance measurement systems in the military literature. Of the 60 military publications reviewed, only 5 percent (3 studies) addressed the relationships between operational and strategic levels of performance and a military organization's goals and objectives. An additional 40 percent of the publications (24 studies) were devoted to other performance measurement

issues. Twelve research reports were concerned with productivity measurement, four reports dealt with capacity measurement, and two theses focused on the development of quality indicators. The remainder of the military publications could be categorized as dealing with competitive edges, system constraints, and Air Force logistics and depot maintenance issues in general. Thus, less than half (45 percent) of the military publications reviewed were directly concerned with performance measurement. Therefore, an opportunity exists to contribute research in an area which has become increasingly important to the AFLC's aircraft repair depots.

In conclusion, the academic publications on performance measurement examined in this literature review primarily concentrated on the performance measurement of functional areas and the productivity measurement of a business unit. They failed to offer insight on how congruency can be developed between operational and strategic performance criteria to ensure that decision making at all organizational levels supports the global goal of the firm. Furthermore, for the most part, the military publications reviewed in this survey failed to address performance measurement in any capacity. Fifty-five percent of the military literature examined dealt with issues like TQM and MRP implementation and depot modernization and logistics shortcomings. These results indicate that more academic inquiry in the performance measurement area, particularly in

performance measurement for military and nonprofit organizations, is necessary.

Productivity Measurement of a Business Unit

Prior to 1980 the academic performance measurement literature generally focused on total and partial productivity models for a business unit or firm (Craig & Harris, 1973; Eilon & Teague, 1973; Gold, 1979). After 1980 various authors continued to address productivity measurement. Bain (1981) provided a productivity measurement audit, outlined six criteria for meaningful measurements, and discussed difficulties in implementing meaningful measurements. Extending the work of Craig and Harris, Hayes and Clark (1985) proposed a total factor productivity measure of efficiency. The American Productivity Center promoted a total performance measurement system that contained indexes of price recovery, productivity, and profitability (Belcher, 1987). Skinner (1986) was one of the few researchers during this period who realized that productivity improvement focused excessively on direct labor efficiency and diverted management attention from other areas like innovation and quality. Not until Son (1990) offered the Integrated Manufacturing Performance Measure (IMPM), however, was a productivity criterion proposed that measured effectiveness, rather than efficiency. The IMPM is defined as the ratio of the total output value to the sum of productivity, quality, and flexibility costs. In addition, output is defined as items

sold, instead of items produced. Thus, the IMPM evaluates long-term manufacturing effectiveness and strategy and indicates how well the firm has achieved its global goal of making money.

During the 1980s several other researchers developed complex multiple-criteria productivity measurement models. English and Marchione (1983) created a productivity determinant model. The objectivity matrix developed by Felix and Riggs (1983) became the basis for the productivity measurement matrix employed by the AFLC from the mid-1980s until early 1991. Sink, Tuttle, and DeVries (1984) presented a taxonomy of three models - the Multi-Factor Productivity Measurement Model, the Multi-Criteria Performance Productivity Measurement Technique, and the Normative Performance/Productivity Measurement Method. Finally, Sherman's (1984) article on the use of data envelopment analysis (DEA), a type of linear programming, for measuring productivity in nonprofit organizations prompted the Air Force Institute of Technology (AFIT) to conduct several studies on the application of this technique.

During the mid-1980s a number of AFIT students wrote theses on the application of DEA and the related technique of CFA (Constrained Facet Analysis) to the productivity measurement of depot and base aircraft maintenance activities (Donovan, 1985; Glaubach, 1985; Gonnerman, 1984; Hitt & Horace, 1984; McKnight, 1985). However, because the

inputs and outputs in all these models were derived from the standard cost accounting measures provided by the AFLC data systems, the validity and usefulness of these models are questionable. Glaubach (1985) did recognize this limitation and concluded that direct product earned hours (DPEH) (the ratio of direct product actual hours to direct product standard hours) was an inaccurate efficiency measure and was disliked by management. Other military productivity studies used linear regression models to predict the productivity of AFLC depot maintenance organizations (Auburn Department of Industrial Engineering, 1980), the Military Airlift Command (MAC) airlift system (Richard, 1980), and the Naval Aviation Rework Facilities (NARFs) (Allton & Bernard, 1981). Additional DOD productivity studies provided military organizations with procedures for developing management indicators and models to track productivity (Howell & Van Sickle, 1982; Norton & Zabel, 1983; Pritchard, Jones, Roth, Stuebing, & Ekeberg, 1987; Tuttle & Weaver, 1986). Still other military studies focused on output measures for hospitals (Armstrong & Dougherty, 1971), an analysis of depot workload (Clark, 1975), and performance indicators for NARFs (Hurley, Jackson, & Leonard, 1985).

Unfortunately, these academic and military productivity studies assumed that traditional cost accounting-based criteria which focus on direct labor and standard costs are relevant for measuring business unit performance. In addition, many of the models proposed in these articles are

generally too complicated for most practitioners to understand and apply to their organizations. However, the major criticism of the productivity measurement literature is that it focuses on only one aspect of organizational performance - productivity. In recent years world class manufacturers and other leading businesses have begun to realize that to remain competitive they need to monitor other aspects of performance, such as quality, delivery, and lead time.

Performance Measurement of Functional Areas

In addition to examining business unit performance, in the 1980s a number of academic researchers investigated performance measurement in the functional areas of manufacturing, such as materials management (Bechtel, 1984; Raedels, 1983; Tetz, 1983), distribution and logistics systems (Cox & Snyder, 1986; Doolan & Myers, 1983), and purchasing (Van Weele, 1984). Other researchers concentrated on measuring the performance of MRP systems (Buker, 1984; Clark, Cox, Jesse, & Zmud, 1982; Cox & Clark, 1984; Edson, 1984; Kauth, 1987) and JIT systems (Crawford, 1988; J. Heard, 1984; Jordan, 1985; Maskell, 1989; McIlhattan, 1987; Stickler, 1989). Clark et al. provided an especially detailed examination of how to audit MRP systems. Stickler recommended the following six measurements: cycle time by product, inventory turns by product, setup times on equipment, output by product per person, quality-rejected

material, and suggestions for improvement by product per day by person.

At this time a few researchers began to address some of the problems with functionally focused performance measures. E. Heard (1984) and Plossl (1987) illustrated how direct labor efficiency and capacity utilization measures are often misused. Howell and Soucy (1987b) discussed the relationship of changes in manufacturing practices to the measurement of quality, inventory, and flexibility. Wantuck (1987) and Crawford (1988) demonstrated how traditional performance measures, such as labor efficiency and machine utilization, are invalid in JIT environments.

During this period military research focused on capacity measurement. Because the DOD depot maintenance community was not satisfied with the methods contained in the DOD capacity measurement handbook (Department of Defense, July 28, 1976), several studies on the measurement of capacity were commissioned. The Logistics Systems Analysis Office (March, 1984), the Rand Corporation (Pyles, Kaplan, Stringer, & Stucker, August, 1987), and the Joint Policy Coordinating Group on Depot Maintenance (November, 1990) made recommendations to the Secretary of Defense for improving DOD capacity measurement methods. With the introduction of TQM in AFLC organizations in 1988, various researchers examined the development of quality indicators for defense contractors (Goertz, 1989) and a quality quotient for predicting quality performance (Hayman &

Schneider, 1989). Harrington and ReVelle (1989) reviewed the quality control program and quality indicators used by Hughes Aircraft.

Thus, even in the late 1980s much research still emphasized optimization of performance in the functional areas, with little discussion of how functional performance was linked to the firm's overall business strategy and objectives. With its emphasis on capacity and other single indicators of performance, the focus of military research was especially narrow. The manufacturing performance measurement literature on MRP and JIT systems started to address how these systems affect business level performance. Still, little was written about the selection of appropriate performance criteria to ensure congruency between manufacturing system performance at the operational level and strategy at the business unit level.

Performance Measurement Linkages

In the military literature reviewed, only three studies discussed the relationships between operational and strategic levels of performance and a military organization's goals and objectives. Connell and Wollam (1968) examined the measurement of aircraft maintenance effectiveness in the Air Force. They asked base aircraft maintenance managers at several command levels to rate the importance of several maintenance effectiveness measures. They also proposed a maintenance effectiveness index (MEDEX) that contained five elements of system performance and three

elements of quality performance. Allen and Linteau (1980) developed a hierarchical framework to analyze the management indicators used by the director of materiel management at SM-ALC. Concluding that only three of 16 operational indicators were useful for decision making at the strategic (directorate) level, they proposed 11 additional indicators that they believed better supported directorate objectives. The most recent study, a report on the repair process for depot level exchangeables (Appelbaum, May 1988), pointed out that current performance measures do not identify repair process bottlenecks or enable managers to determine whether the right items are being repaired. This report proposed a system for aggregating item repair performance by ALC, across weapons systems, and across the command (AFLC).

Academic performance measurement literature focusing on performance measurement linkages began to appear in the 1980s. Most articles provided only a cursory overview of how to achieve these linkages. Janson's (1981) Key Indicator Management (KIM) system involved using organizational goals to establish target values for various functional measures. Groover (1983) examined performance criteria for supply support at a NASA (National Aeronautics and Space Administration) depot. Due-out management and supply effectiveness measures were used to show the linkages required. Piotrowski and Henschen (1984) proposed the concept of "total cycle time" and explained how it affects labor productivity and business strategy in a manufacturing

firm. Cole (1985) explained how information systems can be used to mold a firm's strategy and emphasized putting information at the organizational levels where decisions ought to be made. Goldratt and Fox (1986) illustrated how the operational measures of throughput, inventory, and operating expense can be tied directly to a firm's net profits and return on investment. Armstrong (1987) showed how the maintenance management function has strategic implications for the operation of a business. However, his article did not address implications for performance measurement systems.

Busher and Tyndall (1987) presented ten principles for logistics excellence and a framework for strategically-focused operations which ensures that logistics performance measurement systems are directly linked with corporate strategy. Gooch, George, and Montgomery (1987) suggested seven strategic criteria of manufacturing strength - inventory turns ratio, manufacturing cycle time, product cost, ability to compete internationally, growth rate, market share, and return on investment. Vollmann (1988) offered a framework for changing performance measures and noted a growing congruence between strategic objectives, action programs, and performance measures in leading edge firms. Finally, Fry and Cox (1989) demonstrated the fallacy of using local performance criteria to assess an organization's global performance.

In the last few years more researchers have begun to recognize the role that performance measurement plays in enhancing a firm's business strategy and competitiveness. Adam and Swamidass (1989) contend that research is needed in the manufacturing strategy area on how cost, quality, flexibility, and technology interact to affect business performance. Vollmann (1989) believes that the cost modeling and feedback and control functions of a firm's cost accounting system should be altered to match the organization's strategic objectives. He argues that performance measurement should evolve as strategy evolves. Cox and Blackstone (1990) have proposed a throughput-based performance measurement framework with an external focus. This framework links an organization's strategy and performance measurement systems with its management policies and its logical, physical, and management information systems. Also, researchers at conferences have advocated linking performance measures among all levels of a firm and have illustrated how efficiency and utilization measures can negatively impact overall organizational performance (Iemmolo, 1990; Shapiro, 1990).

Besides the three military studies previously noted, the performance measurement literature survey uncovered several academic articles and books that describe performance measurement system linkages in detail. Richardson and Gordon (1980) pointed out that, while the most frequently used measures related to cost and

productivity are appropriate for mature products, different performance criteria are actually needed for each stage of a product's life cycle. According to these authors, performance measures that are incongruent with a firm's strategy and with a product's life cycle can eventually cause the strategy to become ineffective. Likewise, these findings could imply that, for military organizations, different performance criteria might be required for each stage of a weapon system's life cycle.

Doll and Vonderembse (1987) offered a conceptual framework for integrating computer integrated manufacturing (CIM) with business strategy. They claimed that as firms develop competitive applications of CIM technology, changes in strategic thinking and manufacturing performance will occur. Similarly, the CAM-I CMS study (Brimson & Berliner, 1988) provided a conceptual framework for understanding the interrelationships between organizational goals and performance measurement. However, it focused internally on improving cost management and failed to examine the external impact of organizational performance on the customer.

Bowersox, Dougherty, Drogue, Rogers, and Wardlow (1989) conducted a comprehensive study of leading edge logistics firms which examined 38 performance measures in five areas - cost, customer service, asset management, quality, and productivity. These researchers discovered that the performance measurement practices of these firms were fairly similar in the areas of cost, customer service,

and asset management, but were less uniform in the areas of quality and productivity. The key problem that logistics managers expressed with their performance measurement systems concerned the scope and relevancy of performance criteria.

The Cleveland, Schroeder, and Anderson (1989) study advocated production competence as the link between production process and business strategy. These authors contended that the combination of process and strategy determines production competence. They formulated a process-strategy matrix combining four types of production processes and four kinds of business strategies. They also designed and validated a diagnostic procedure for assessing manufacturing's capability relative to a firm's business strategy.

Schroeder, Scudder, and Elm (1989) used data obtained from 65 manufacturing managers on what manufacturing innovation is, how it can be measured, and how it can be improved to develop a framework for manufacturing innovation. The framework illustrates how manufacturing results are influenced by the degree of manufacturing innovation present and by various factors external to the firm. The degree of innovation is affected by several internal manufacturing elements that can be managed by the firm, such as resources, structure, goals, and culture. These authors recommended that measurements of innovation should focus on the amount and type of new ideas tried in

manufacturing and cautioned that innovation measurements should be differentiated from manufacturing performance results.

Though the operational measures of throughput (T), inventory (I), and operating expense (OE) and the control measure of inventory dollar days were introduced in an article by Sorrell and Srikanth (1985), they were fully defined by Goldratt and Fox (1988). These researchers showed how T, I, and OE are linked to the strategic criteria of net profit and return on investment. Their definitions for T, I, and OE (1988, p. 4) are provided below.

<u>Throughput</u>: The rate at which the system generates money through sales

<u>Inventory</u>: All the money the system invests in purchasing things the system intends to sell

<u>Operating Expense</u>: All the money the system spends in turning Inventory into Throughput

Goldratt and Fox argued that control measures, such as local operating expense, are needed for subsystems to make managers aware of deviations from the plan. Two types of deviations exist. The criterion of throughput dollar days measures due date performance and assesses the first type of deviation - things that were supposed to be done but were not done. The second type of deviation, things that were not supposed to be done but nevertheless were done, is measured by inventory dollar days. Goldratt (1990b) also stressed that performance measurements are a direct result

of the firm's chosen goal. Because he assumed that the goal of the company is to make money now and in the future, he conceded that his performance measurement analysis may not strictly apply to nonprofit organizations. Consequently, even though AFLC is technically a nonprofit organization, defense budget reductions and the advent of competition are forcing the command to operate more like a for-profit business. As a result, this researcher believes that Goldratt and Fox's measures could prove useful for various AFLC depot maintenance organizations.

Two recent books on manufacturing performance measurement cite the need to integrate strategies, action programs, and performance measures (Dixon, Nanni, & Vollmann, 1990) and the importance of performance measurement for fostering continuous improvement (Hall, Johnson, & Turney, 1991). According to Dixon et al., cost-based measures are inconsistent with the JIT and TQM philosophies, and outmoded performance measurement systems are hindering the restructuring necessary for firms to become more competitive. These researchers introduce a tool for changing performance measurements called the Performance Measurement Questionnaire (PMQ). The PMQ focuses on competitive priorities and the extent to which a company's measurement systems support or impede the achievement of these priorities.

Hall et al. demonstrate how performance measurement is built into the new customer-centered manufacturing paradigm,

which encompasses improvement in three broad areas - people, process, and quality. An overall set of performance measures should relate to the major improvement goals of quality, dependability, waste (resource) saving, flexibility, innovation, and development of people. These authors also advocate activity-based cost systems for linking financial planning and nonfinancial controlling information. More importantly, they provide two graphic examples of this linkage. An illustration on the hierarchy of measurements at General Electric shows how this company links its operating level performance measures to its internal indicators and its global key success factors. Another figure on policy depployment in a fastener company explicitly illustrates the linkages between long-term strategic policy and annual objectives, tactical plans, and operational performance measures.

The goals and performance measurement systems at each level of the organization must be congruent with each other to achieve system objectives. However, as Lockamy (1991) argues, little research examining the linkages of the various levels of a business has been conducted. With the exception of Lockamy's (1991) study, no empirical research on this area was found. In addition, the recent academic publications that emphasize the need to link operational performance measures to business unit objectives tend to assume that the operational and strategic levels of the firm share the same objectives. Moreover, no research examining

the congruency of strategic goals and operational objectives has been conducted in a military setting.

Performance Measurement and Competitive Edges

As more U.S. companies began implementing JIT manufacturing and TQM during the 1980s, academicians began to question the relevancy of the traditional cost accounting-based performance measurement systems commonly found in American manufacturing firms (Bruns & Kaplan, 1987; Johnson & Kaplan, 1987; Kaplan, 1983; Kaplan, 1984). Cost accounting systems based on JIT practices were proposed (Howell & Soucy, 1987b; McIlhattan, 1987; McNair, Mosconi, & Norris, 1989), as well as Cost Accounting by Goals and Strategies (CAGS) (Nanni, Miller, & Vollmann, 1988). McNair et al. argued that the final goal of a management accounting system (MAS) is the development of a total performance measurement system that integrates organizational activities across various managerial levels and functions. In the MAS proposed by these authors, actual costs replace standard costs and the following areas are targeted for measurement: process time, obsolescence, elimination of defects, parts standardization, and velocity of materials. In addition, Schiff and Schiff (1988) discussed new cost accounting techniques utilized in conjunction with the acquisition of the F-16 aircraft.

Meanwhile, researchers in the military sector focused on issues concerning TQM implementation (Baldwin, 1990; Fargher, 1990; Farmer, 1989; Hansen, 1989; Springs, 1989;

Warmington, 1988) and MRP implementation in a remanufacturing environment (Boyer, 1987; McHugh, 1988; Ward, 1990). In his study on depot maintenance quality, Smith (1985) reported that misuse of the Quality Deficiency Reporting (QDR) system deprives depot managers of the data needed for analysis to improve the quality of maintenance products. He cited nine reasons why customers in the field do not report defects. He also contended that the certification of maintenance production technicians to inspect their own work has led to a significant decrease in customer-reported defects. Hansen pointed out that, while AFLC is a vertical organization, its processes are horizontal and are developed around support for weapon systems. He emphasized the importance of ownership and of employing Process Action Teams (PATs) as tools to cut across functional areas. Warmington outlined eleven lessons learned from TQM implementation at the North Island Naval Aviation Repair Facility, and Fargher detailed the TQM implementation model employed at the Cherry Point Naval Aviation Depot. Farmer explained how to apply TQM to base-level maintenance organizations, and Springs identified Air Force points of contact for TQM implementation. Finally, Baldwin provided examples of success stories resulting from TQM implementation at the Sacramento ALC.

Although a majority of the 26 publications reviewed in this section of the literature survey relate to the competitive edges of cost and quality, a limited number of

books and articles containing discussions on the measurement of delivery, innovation, and flexibility have been published. Miller's (1990) analysis of shipping performance measurements is one of the few articles devoted exclusively to the measurement of delivery performance. As previously noted, Schroeder et al. provide a framework for measuring and improving manufacturing innovation. Cox (1989) discusses performance measures for product-mix flexibility and volume flexibility. Dixon, Nanni, and Vollmann (1990) present a flexibility framework which has four dimensions associated with quality, product, service, and cost. However, even though flexibility and innovation are recognized as critical success factors, the measurement of these competitive edges poses challenges to researchers and practitioners alike.

In the last couple of years, several books and articles on time-based competition have appeared. The works of Stalk (1988), Stalk and Hout (1990), Blackburn (1991), and Schmenner (1991) demonstrate the importance of using time-based measures to reduce lead time and improve customer delivery performance. Stalk observes that time-based manufacturing practices differ from traditional manufacturing practices along three dimensions - the length of production runs, the organization of process components, and the complexity of scheduling procedures. Stalk and Hout note that time and quality measures reinforce each other, while time and cost measures conflict with each other.

Blackburn asserts that JIT concepts are the key to the time-compression process. However, time-based competition encompasses not only manufacturing but the entire value-delivery chain of a service or product. Based on the results of a worldwide survey of manufacturing practices, Schmenner cited ten variables which explain differences in productivity. These variables include throughput-time reduction, less inventory, improved quality, and overtime.

Focusing on the competitive edges to improve business performance has proven useful in for-profit environments. Nonetheless, no research has been conducted in nonprofit environments to ascertain the importance of various competitive edges on accomplishing the objectives of these organizations. With the DOD's recent encouragement of competition among all military depots, the need for empirical research on the applicability of competitive edges in a military setting is obvious.

Performance Measurement and System Constraints

Because this study deals with performance measurement in AFLC's aircraft repair depots, the literature in this section is derived almost entirely from military sources, such as GAO reports and Air Force Magazine articles. Taylor's (1989) thesis on organizational change and Canaan's (1989, 1990, 1991) articles offer insights on what the Air Force must do to adapt and survive in this era of defense budget reductions and military drawdowns. Grier (1989) relates how AFLC is focusing its repair operations on

problems that ground aircraft. Fry (1989) explains how the Logistics Management Systems (LMS) program of computer modernization is improving the way AFLC manages its core functions of logistics requirements, acquisition, distribution, and maintenance.

Recent articles in the Air Force Journal of Logistics address improvements in various logistical functions. Gebman and Snyder advocate serial number tracking of avionics equipment (1989) and the adoption of a new indicator, fault removal efficiency, for avionics maintainability (1990). King and Lucuk (1989) report the benefits of an integrated database system for depot stock control and distribution. Alcorn and McCoy (1991) illustrate how PACER INTEGRATE has improved distribution support to depot maintenance. Lewandowski (1991) explains how the concept of stock funding of depot level reparables will drive Air Force managers at all levels to adopt a more business-like approach.

Other publications demonstrate how the Distribution and Repair in Variable Environments (DRIVE) program can be used to prioritize depot repair and distribution actions in order to maximize aircraft availability (Bond & Ruth, 1989), discuss barriers to TQM implementation in DOD (Rumsey & Miller, 1990), and point out constraints in fiscal management which are unique to DOD and AFLC (Falldine, 1991). Numerous reports by the Government Accounting Office (GAO) and other agencies (Air Force Audit Agency, 1989; DCS

Maintenance, 1990) highlight problems in AFLC logistics systems and the need to streamline depot maintenance (Beyer & Stevenson, 1986; Glass & Schwartz, 1989). While the majority of the GAO reports (March 18, 1988; December 7, 1989; March 26, 1990) deal with problems regarding inventory management and contractor access to the DOD supply system, one report (June 18, 1990) relates that improvements are needed in the Navy's aircraft engine repair program. Another GAO report concerned with work measurement (June 8, 1981) and the Air Force audit agency report highlight inaccuracies in AFLC's estimated labor standards and shop flow day standards. Beyer and Stevenson discuss the need for industrial modernization in the Navy and Air Force depots. Glass and Schwartz propose a modernization strategy for DOD maintenance depots which consists of simplifying processes first and then considering automation of processes and of information systems for scheduling and controlling inventory.

As the previous studies indicate, numerous problems are encountered in Air Force logistics management. Even though these problems consume considerable time and resources, they do not represent the constraints to the system. No research has been conducted applying Theory of Constraints (TOC) and effect-cause-effect (ECE) analysis to identify the major obstacles to improving AFLC effectiveness.

In summary, performance measurement system research in the production/operations management field has evolved from

focusing on the measurement of productivity and of functional areas to an exploration of the relationship between operational performance measures and strategic goals and key success factors. However, the current body of performance measurement research, particularly in the military literature, still presents a disjointed approach to the study of operational and strategic performance measurement systems. The failure to place performance measurement in the context of an overall system, like the Air Force depot maintenance system or the Air Force logistics system, exacerbates this fragmentation. Moreover, research that does cite the need for linking operational performance criteria with strategic objectives tends to assume that all levels of the organization share common objectives. The lack of research in nonprofit organizations on the importance of competitive edges for accomplishing organizational objectives and on the identification of system constraints and their relation to the performance measurement system illustrates the need to utilize more of a systems approach in performance measurement research efforts.

Even though recent publications have begun to emphasize the importance of congruency between an organization's objectives and performance criteria, little has been written, especially in regard to nonprofit environments, about such congruencies across vertical and horizontal functional boundaries. Although AFLC has recently reduced

the number of vertical layers in its command structure, the organization still contains many horizontal boundaries. These horizontal barriers stem from the command's mission, which revolves around weapon systems support. According to Hayes and Wheelwright (1984), horizontal activities that cut across several functions require more coordination and consistency than do vertical activities between organizational levels. A performance measurement system that provides solid linkages between operational and strategic levels and across horizontal processes and functional boundaries represents a viable means for improving organizational coordination and system performance. Unfortunately, few examples exist in the academic or military performance measurement literature on how to develop the performance measurement criteria and linkages needed to enhance managerial decision making and the accomplishment of strategic goals and objectives. This deficiency, along with the other shortcomings in the performance measurement literature revealed by this literature survey, made it apparent that a study on performance measurement in a nonprofit organization was needed.

CHAPTER III

RESEARCH METHODOLOGY

The research paradigm employed for this dissertation consisted of an adaptation of Schendel and Hofer's (1979) general research paradigm (pp. 388-389) and Babbie's (1986) social research paradigm (p. 83). Figure III-1 provides an overview of the dissertation research process. The topic selection was based on the researcher's personal interest and experience and the realization that AFLC performance measurement systems are outmoded. Once the topic was chosen, the research questions were developed, the research methods were selected, and the population to be studied was identified (sample selection).

Research Questions

The research questions for this study are as follows:

(1) Is there congruence between the goals of the Air Force Logistics Command (AFLC) and the depot-level and directorate-level objectives of its aircraft repair depots?

(2) Do managers at the directorate, division, branch, and first-line supervision levels agree on the ranking of the criticality of the competitive edges for accomplishing depot maintenance?

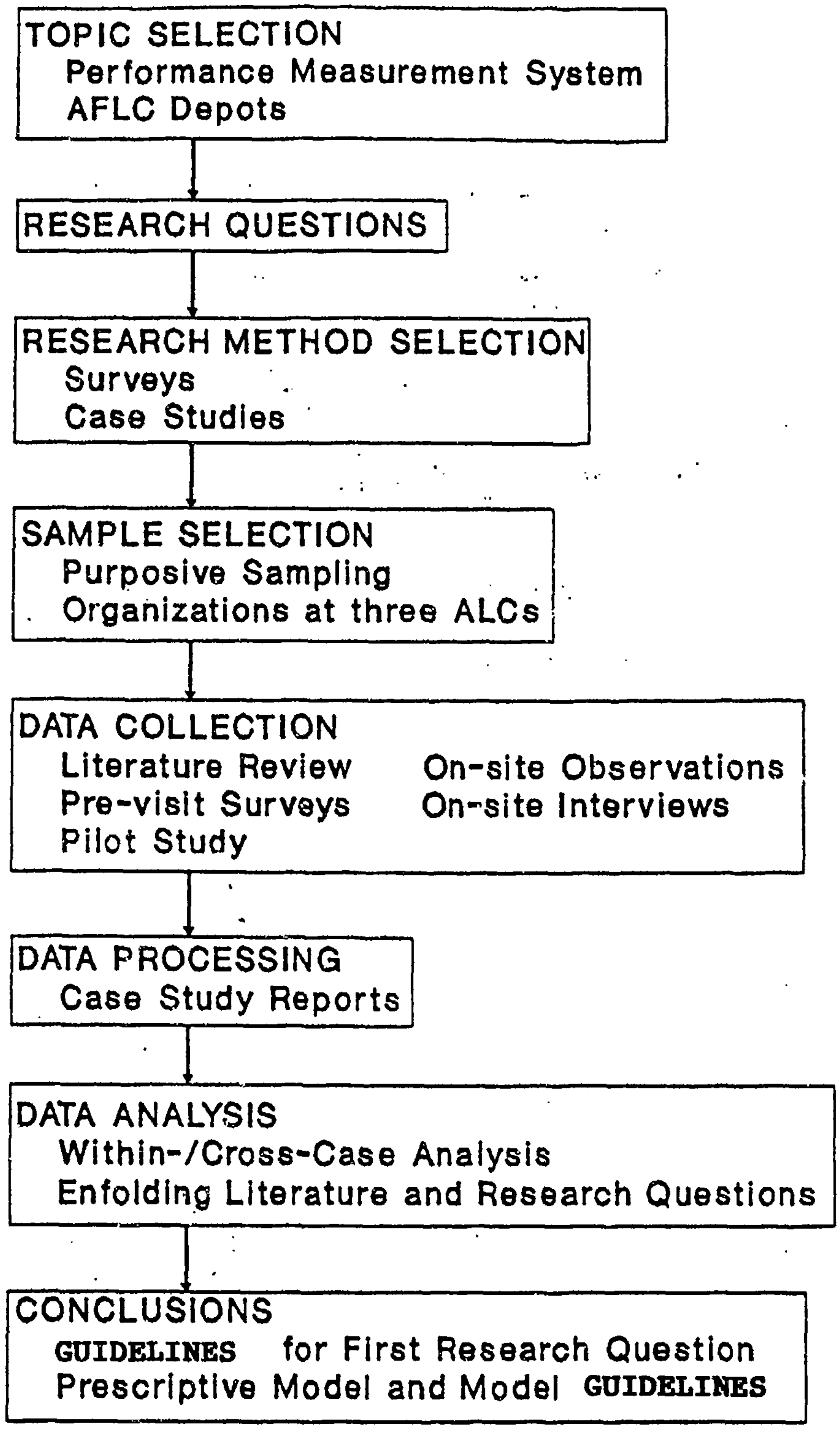


Figure III-1. Steps in the Research Process

(3) Do performance criteria used at the directorate, division, and branch levels support the accomplishment of AFLC goals and directorate and depot objectives? If not, what are some criteria that would better support these organizations' objectives?

(4) What types of constraints exist in these depots, and how do these constraints impact depot performance?

Research Methods

Because this study is of an exploratory nature, an empirical research methodology was required. To obtain the depth of understanding needed for theory building and for developing the depot maintenance performance model and the associated set of guidelines, the case study research design was determined to be the most suitable research methodology. Survey instruments in the form of questions asked prior to and during the field studies were also used in this dissertation.

Yin (1984) defines a case study as an empirical inquiry that investigates a contemporary phenomenon within its real-life context when the boundaries between phenomenon and context are not clearly evident and which uses multiple sources of evidence. He observes that the case study is a research design particularly suited to situations where it is impossible to separate the phenomenon's variables from their context. Merriam (1988) notes that the case study offers a means of investigating complex social units consisting of multiple variables of potential importance in

understanding the phenomenon. One of the strengths of the case study method is the in-depth understanding it offers a researcher of the dynamics present within a single setting (Babbie, 1986). This method is especially useful for applied fields of study and for bringing about an understanding of processes and problems that can affect and improve practice (Merriam, 1988). In summary, case studies may involve single or multiple settings and can be used for providing descriptions, testing theory, and generating theory (Eisenhardt, 1989).

For this dissertation, the case study method was used to build theory. Schendel and Hofer (1979) provide an overview of concept development and theory building. The purpose of concept development is to draw maps of the territory and identify key variables that may be used to describe the phenomena of interest. The use of a few, focused in-depth case interviews is one of the best ways to develop new conceptual models (Schendel & Hofer, 1979). The pre-visit questionnaires and on-site interviews for this research effort focused on the managers of a few selected directorates, divisions, and branches deemed critical to the accomplishment of depot maintenance for a particular aircraft.

Eisenhardt (1989) cites three advantages of building theory from cases. These strengths are the likelihood of generating novel theory, of generating testable theory, and of developing a theory that is empirically valid. Because

the theory-building process is intimately tied with the actual evidence, the resultant theory tends to closely reflect reality. This research project consisted of studying the performance measurement systems of six AFLC depot maintenance organizations for the purpose of generating a depot maintenance performance model and an associated set of guidelines. For this model and its guidelines to be of value to AFLC practitioners, empirical validity is essential and testability is highly desirable.

A model is a "mental construct which is a unit in a body of theory" (Galt & Smith, 1976, p. 27). Schendel and Hofer (1979) define a prescriptive model as a model containing variables controllable by management and used to describe what "can be" insofar as any given "can be" is possible in the real world. Little (1970) and Morris (1967) have identified certain characteristics for evaluating the usefulness and understandability of models. The following characteristics were used to evaluate the prescriptive model derived from this research: robustness, simplicity, completeness on important issues, ease to communicate with, and fertility of consequences.

Sample Selection

Even though there is no ideal number of cases required for building theory, Eisenhardt (1989) believes that a number between four and ten cases works well. She points out that with fewer than four cases, generating theory with sufficient complexity and empirical grounding is often

difficult. On the other hand, with more than ten cases, the researcher finds it hard to cope with the complexity and volume of the data. Thus, because only a limited number of cases can usually be studied, it makes sense to choose cases that are likely to replicate or extend the emergent theory. Purposive sampling was used to select the AFLC depots and organizations that participated in this study. Purposive sampling is based upon the assumption that the researcher wants to gain insight and understanding. Therefore, one needs to select a sample from which the most can be learned (Merriam, 1988). The actual sample selection was based on factors such as whether a depot's top management expressed interest in and willingness to support this study, was involved in implementing new production techniques and other changes in the depot maintenance process, and had been educated in current practices like TQM, JIT, and TOC. The selection process resulted in a cross-section of interrelated organizations at three of AFLC's five aircraft repair depots.

This research focused on depot maintenance for six types of aircraft at three different ALCs - Ogden ALC (OO-ALC) at Hill AFB, Utah; Sacramento ALC (SM-ALC) at McClellan AFB, California; and Warner Robins ALC (WR-ALC) at Robins AFB, Georgia. The key directorates involved in this research (designated by the second row of boxes) and their primary types of aircraft and exchangeables are shown in Figure III-2 (A/C refers to aircraft and COMMOD designates

commodities). Various branch-level job shops in the Technology and Industrial Support (TI) Directorates at the Sacramento and Warner Robins ALCs were also examined. The aircraft production divisions that were studied at the Ogden and Sacramento ALCs, as well as the commodities divisions that were examined, are shown in the third and fourth rows. The sample selected for the study represented a cross-section of the types of aircraft repaired by AFLC as well as the kinds of depot maintenance performed by the command. For example, the dissertation examined depot maintenance

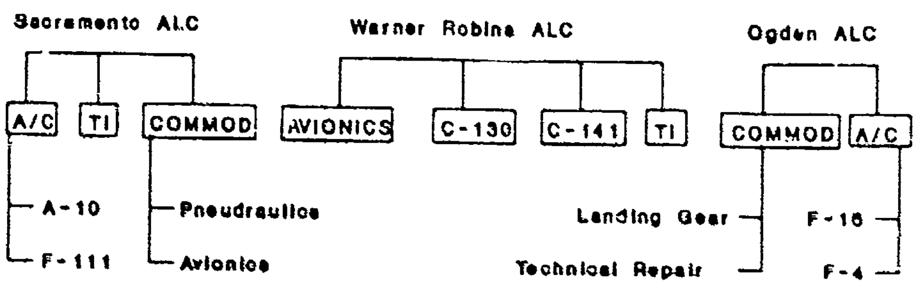


Figure III-2. Abbreviated Organizational Chart for ALCs

for the Air Force's newest fighter jet (the F-16) and its oldest cargo plane (the C-130). In addition, depot maintenance for half of the organizations in the study (C-130, F-111, and F-4) mainly consisted of programmed depot maintenance (PDM), while that for two of the other organizations (A-10 and F-16) focused on modification

programs. C-141 depot maintenance involved both PDM and major modifications.

Data Collection

Pre-visit questionnaires, on-site observations, and on-site interviews were used to supplement data from the literature review. Lessons learned in conducting the pilot study in the C-130 depot maintenance organization at WR-ALC were used to refine the data collection and focus the pre-visit questionnaires and interview instruments more sharply on the research questions. Separate pre-visit questionnaires for the directorate and division levels were employed to familiarize the researcher with depot operations, to help identify critical functions for on-site investigation, to assess congruency between AFLC goals and depot objectives and between performance criteria and depot objectives, and to assess the importance of certain competitive edges. Also, surveys to assess the importance of the competitive edges and to ascertain the key performance criteria were administered on site to selected branch chiefs and first-line supervisors. Thus, managers at four organizational levels - directorate, division, branch, and first-line supervision - were required to rank the six competitive edges (cost, quality, delivery, lead time, product/process innovation, and product/process flexibility). The results of the pre-visit questionnaires and surveys were analyzed to determine congruency ratings and to ascertain whether agreement existed on the relative

importance of the competitive edges between functional areas (aircraft versus support directorates) and between organizational levels. Copies of the pre-visit questionnaires and on-site surveys are provided in the Appendix.

On-site interview instruments for use at directorate, division, and branch levels were used to ensure that similar data was collected from the six depot maintenance organizations at the three ALCs. All questions included in the interview schedules were open-ended, rather than closed-ended. Open-ended questions are the type recommended by Miles and Huberman (1984) for exploratory studies. Two versions of this interview schedule were developed. The first version contains the general interview questions, as well as sub-questions designed to explore the question area in greater detail. The second version contains only the general interview questions and was given to directorate and division-level interviewees prior to the discussion. Using these two versions of the interview instrument enabled the researcher to obtain all the necessary information pertaining to a question area and lessened the likelihood of interviewee response bias and researcher bias. Bruns and Kaplan (1987) report that researchers tend to retain those observations that are understood and not pursue those comments that are not understood. Copies of the interview schedules are given in the Appendix.

Data Processing and Analysis

Observation and Processing

Three-day site visits were made to each depot maintenance organization to collect the required data. One- to two-hour interviews were conducted with directorate and division chiefs to determine the competitive edges, explore the performance criteria used, and ascertain the primary system constraints. Key branch chiefs in selected divisions were also interviewed for 30 to 60 minutes to obtain their views on these same topics. First-line supervisors were briefly interviewed as time permitted. Notes were taken during all interviews, which were recorded upon permission.

Following the depot site visits, a case study for each depot maintenance organization was written. The cases incorporate information obtained from all data collection methods, including interviews, observations, and collected materials. All interviews, except those conducted in WR-ALC's Avionics Directorate's production division, were recorded. Tapes were transcribed by the researcher to ensure data accuracy. All directorates in each depot maintenance organization at each of the three ALCs had the opportunity to review and revise the case studies applicable to their organizations.

Data Analysis

Overview

Data were analyzed in relation to the four research questions. The analysis consisted of within-case analysis

and cross-case pattern searches. Citing the work of Pettigrew and Gersick, Eisenhardt (1989) observes that within-case analysis generally involves detailed case study write-ups for each site that are central to the generation of insight. The purpose of these write-ups is for the researcher to become intimately familiar with each case as a stand-alone entity. To become familiar with each case, this researcher reviewed numerous documents and utilized narrative, tabular displays, and summary tables. Additional types of data analysis peculiar to each research question are discussed in separate sections following this overview section.

The cross-case pattern search is an extension of within-case analysis. While there are many ways to accomplish cross-case analysis, this researcher developed cross-case comparison tables for AFLC goals and depot objectives, competitive edge rankings, and commonly used performance criteria. Comparison or summary tables were also created to highlight the similarities and differences between the rankings and various test results related to the congruency of AFLC goals and depot objectives and of AFLC performance criteria and depot objectives. Finally, an ECE diagram displaying the most common constraints identified by research participants was constructed. According to Miles and Huberman (1984), narrative text alone is too weak and cumbersome for presenting information in a systematic manner. They recommend the use of displays, like tables,

for highlighting similarities and differences and allowing for a more refined data analysis. The summary and comparison tables improved the probability of developing valid guidelines and a model that closely fit the data. As Eisenhardt (1989) observes, a close fit is critical to building good theory because it takes advantage of new insights possible from the data and yields a theory which is empirically valid. Once the data analysis was completed, guidelines related to each of the four research questions were formulated. In addition, a depot maintenance performance model showing the relationships among and the elements comprising the four primary variables was created.

AFLC Goals and Depot Objectives

For the first research question, the primary data examined were the Likert scale rankings provided to question 4 in part B of the pre-visit directorate-level and division-level surveys. Two or three directorates and between three and six divisions at each of the three ALCs in this study were sampled. Respondents were asked to rate the extent to which they believed their ALC and directorate objectives supported AFLC's goals. A rating scale of 1 to 4 was used, with 1 indicating no extent, 2 designating slight extent, 3 representing significant extent, and 4 equating to great extent. For each case, a Mann-Whitney U test was conducted to determine whether a significant difference existed between the mean rankings of the directors and division chiefs of aircraft product directorates (i.e., C-130, C-141,

and aircraft directorates) and the directors and division chiefs of supporting directorates (i.e., commodities, avionics, and technology and industrial support directorates). The hypothesis tested was as follows:

> Ha: The mean ranks do not come from the same population.

Based on the results of these tests and of data from the on-site interviews, guidelines were developed regarding congruency between AFLC goals and depot objectives.

Competitive Edges

To develop guidelines for the second research question, statistical analysis was used to assess the applicability of the competitive edges to a nonprofit environment. To determine whether significant differences existed between the mean rankings of competitive edges at the directorate and division versus the branch and first-line supervision levels, median tests were conducted on the survey results for each case. Two additional issues were also explored within each case and across cases. The first factor concerned ascertaining whether significant differences existed between aircraft product and supporting directorates within and across depot maintenance organizations (C-130, F-16, etc.) on the importance of the competitive edges. The second factor involved examining whether there were significant differences among the competitive edges themselves, as determined by the aircraft product and supporting directorates within and across depot maintenance

organizations. To address these two factors, median tests and Friedman Two-Way Analysis of Variance of Ranks tests were conducted on the survey results.

For each case, managers at four levels - directorate, division, branch, and first-line supervision - were asked to rank the importance of the competitive edges of cost, quality, lead time, delivery, product/process flexibility, and product/process innovation for accomplishing depot maintenance on their particular type of aircraft. One set of rankings was based upon unit objectives, while the other set was based on the criteria, or management indicators, used to report unit performance. To determine whether significant differences existed between the mean rankings of the competitive edges themselves, Friedman Two-Way Analysis of Variance of Ranks tests were conducted on the two sets of rankings. The hypothesis tested for each set of rankings is provided below:

Ha: Significant differences exist between the mean ranks of the competitive edges.

Bonferroni Pairwise Comparison tests were used to highlight where the differences existed.

In addition, median tests were used to determine whether differences existed between higher-level (directorate and division) managers and lower-level (branch and first-line) supervisors on the rankings of individual competitive edges. The hypothesis tested was as follows:

Ha: Organizational level is a significant factor in the mean rankings of each competitive edge.

Finally, median tests were also utilized to ascertain whether differences existed between all levels of aircraft managers and all levels of managers from supporting directorates on individual competitive edge rankings. The hypothesis tested was as follows:

Ha: Organizational function is a significant factor in the mean rankings of each competitive edge.

Performance Criteria

For the third research question, the Likert scale rankings provided to questions 6 and 9 in part C of the pre-visit directorate- and division-level surveys and to question 5 of the on-site branch and first-line supervision surveys were examined. Managers at four levels - directorate, division, branch, and first-line supervision - were asked to rate the extent to which they believed their organization's management indicators supported their depot and directorate objectives and command goals. A rating scale of 1 to 4 was used, with 1 representing no extent, 2 indicating slight extent, 3 designating significant extent, and 4 denoting great extent. To determine whether significant differences existed between the mean rankings for congruency of depot objectives and performance criteria at the directorate, division, branch, and first-line supervision levels, Mann-Whitney U tests were conducted on

the survey results for each case. The following hypothesis was tested:

Ha: The mean ranks do not come from the same population.

In addition, cross-case pattern searches were employed to identify the current performance criteria most widely used by the research participants at the various levels. Because the results of the Mann-Whitney U tests and the cross-case analysis indicated that, on the whole, current AFLC performance criteria are not internally consistent with the goals and objectives identified by the first research question, new criteria were proposed. The new criteria are presented in Chapter VI. These new performance criteria were based on what has been identified as appropriate criteria by leading performance measurement researchers and by individuals at AFLC organizations who have been educated in Theory of Constraints (TOC) concepts.

System Constraints

Effect-cause-effect (ECE) diagrams and Theory of Constraints (TOC) principles were utilized to respond to the fourth research question and identify the root problems and constraints that have the greatest impact on depot maintenance for each depot maintenance organization in this study and for AFLC in general. Using the ECE diagrams displayed at the end of the C-130, C-141, F-16, and A-10 cases, an overall ECE diagram for AFLC depot maintenance was constructed. Based on the conceptual framework in Figure

I-1 and a thorough review of the within-case and cross-case analyses, a prescriptive depot maintenance performance model and associated set of guidelines were developed. To adhere to the characteristics previously mentioned for model evaluation, the model included only the strategies, competitive edges, performance measurement system components, and constraints truly critical to depot performance.

CHAPTER IV

CASE STUDIES

C-130 Depot Maintenance

Warner Robins ALC, Georgia

Introduction

Air Force Logistics System

Before examining the C-130 depot maintenance operation, an overview of the Air Force logistics system and the organizational structures of the Air Force Logistics Command (AFLC) and the Warner Robins Air Logistics Center (WR-ALC) will be presented. Within the Department of Defense (DOD) logistics system, the Secretary of Defense may be thought of as the chief executive officer (CEO) and the separate military departments, of which the Air Force is one, as operating divisions (Geisler et al., 1977). Depot maintenance for 580 ships, 24,000 aircraft, and nearly 700,000 combat and wheeled vehicles is performed at various contractor facilities and at 33 organic facilities - Army Depots, Naval Air Rework Facilities, Naval Shipyards, Marine Corp Logistics Bases, and Air Force Air Logistics Centers (ALCs) (Beyer & Stevenson, 1986).

The Air Force logistics system provides support for missiles, munitions, vehicles, and aircraft, with aircraft consuming the largest portion of logistics resources

(Geisler et al., 1977). Figure IV-1, adapted from the study conducted by Geisler et al., is a simplified representation of the elements of the Air Force logistics structure that support aircraft operations. The left side shows the flow of aircraft and/or components in the logistics support cycle, while the right side depicts aircraft flow in the operational cycle. Base maintenance is the link between these two cycles. Depot maintenance acts as the wholesaler for base maintenance, performing overhauls of engines and aircraft and component repairs beyond base maintenance capability. While aircraft that have been overhauled at depot normally return to their original base, engines and component items (known as "exchangeables" in AFLC terminology) generally enter depot stock once they have been repaired and are managed by central supply as inventories available for redistribution to various base supplies (Geisler et al., 1977).

AFLC Organization

Through its five ALCs located at Ogden, Utah, Oklahoma City, Oklahoma, Sacramento, California, San Antonio, Texas, and Warner Robins, Georgia, the Air Force Logistics Command (AFLC) buys, supplies, repairs, and transports everything needed to keep the Air Force ready for combat (Fry, 1989). Since 1975 the Air Force has employed a Technology Repair Center (TRC) concept whereby work in a particular technology is assigned to a single ALC (Beyer & Stevenson, 1986). For

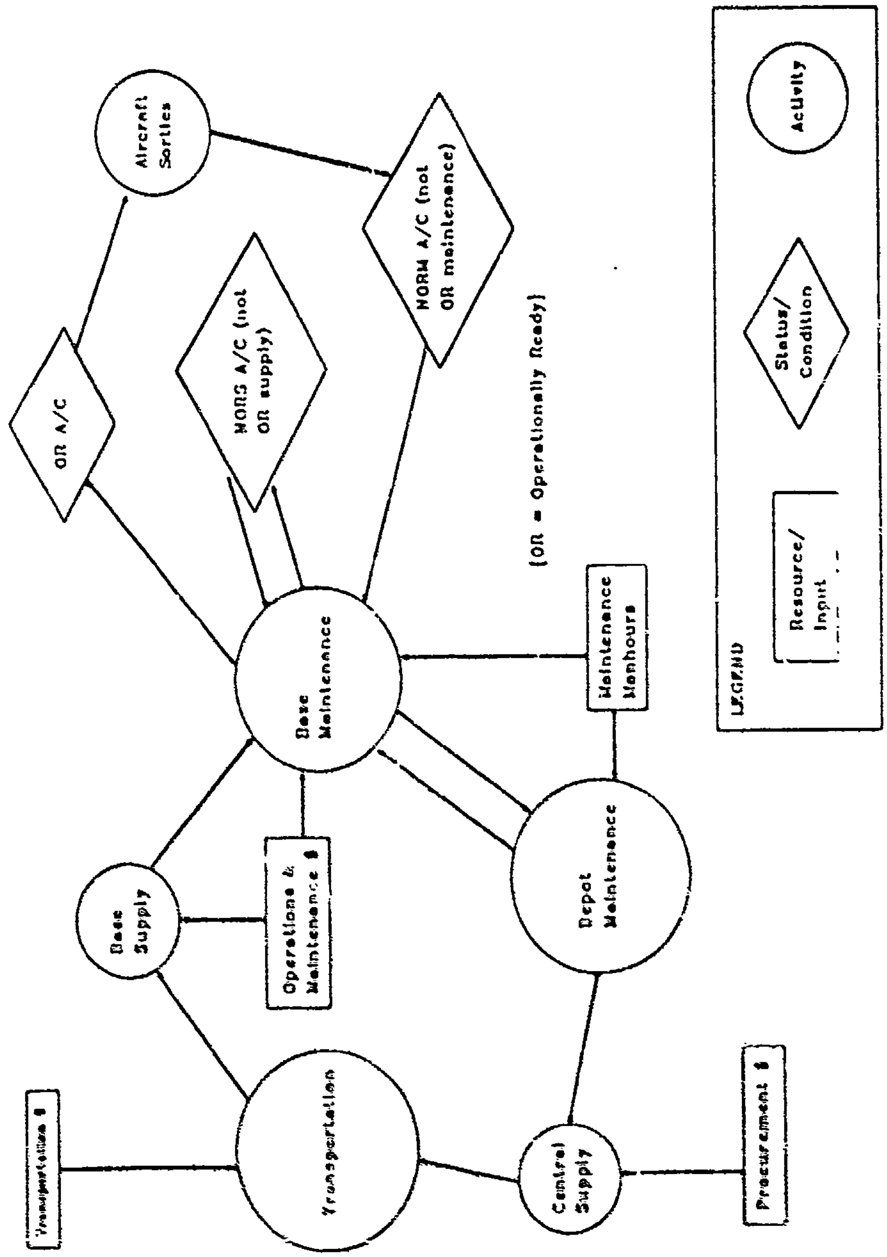


Figure IV-1. Air Force Logistics Structure

example, all aircraft landing gear are repaired by the Ogden ALC (OO-ALC).

To minimize vulnerability and balance workloads, AFLC has recently begun to redistribute technology repair and aircraft overhaul among the five ALCs. For instance, programmed depot maintenance (PDM) for C-130 aircraft is performed at OO-ALC and WR-ALC. Modifications on F-15 aircraft are now done at both Sacramento ALC (SM-ALC) and WR-ALC (DCS Maintenance, 1990).

AFLC Goals

The Air Force Logistics Command (AFLC) has designated four drivers - people, quality, mission, and environment - to help it achieve its vision of "Partners in Excellence". The command's mission of satisfying its customers by providing them "Combat Strength Through Logistics" reflects its strong customer-oriented philosophy (Grapes, 1991). The 13 goals outlined by the AFLC commander are listed in Figure IV-2 and are divided among three broad categories - people, user support, and quality.

Warner Robins ALC (WR-ALC)

In October, 1990 the functional organizational structure at the five ALCs was replaced with a new system of directorates structured along product and service lines (West, 1990). As illustrated by the WR-ALC organizational chart in Figure IV-3, this restructuring has been the most extensive at Warner Robins. The F-15, C-130, and C-141

People:

Improve **Quality of Life** whenever possible

Provide **Recognition** for outstanding performers

Ensure **Personal Accountability** at all levels

Trust our people to do their job right the first time

Recognize our work force as **True Warriors**

User Support:

Make **Customer Satisfaction** a top priority

Achieve **Organizational Realignments** to improve system support

Enhance **Requirement ... orecasting Credibility**

Quality:

Assure that **Quality Comes First**

Involve **Everyone at Every Level** - no bystanders

Include **All AFLC Processes**

Make **Continuous Improvement** a way of life

Develop **Pride of Ownership** through **Pride of Workmanship**

Figure IV-2. AFLC Commander's Goals

(Source: AFLCVA 190-32, May 1989)

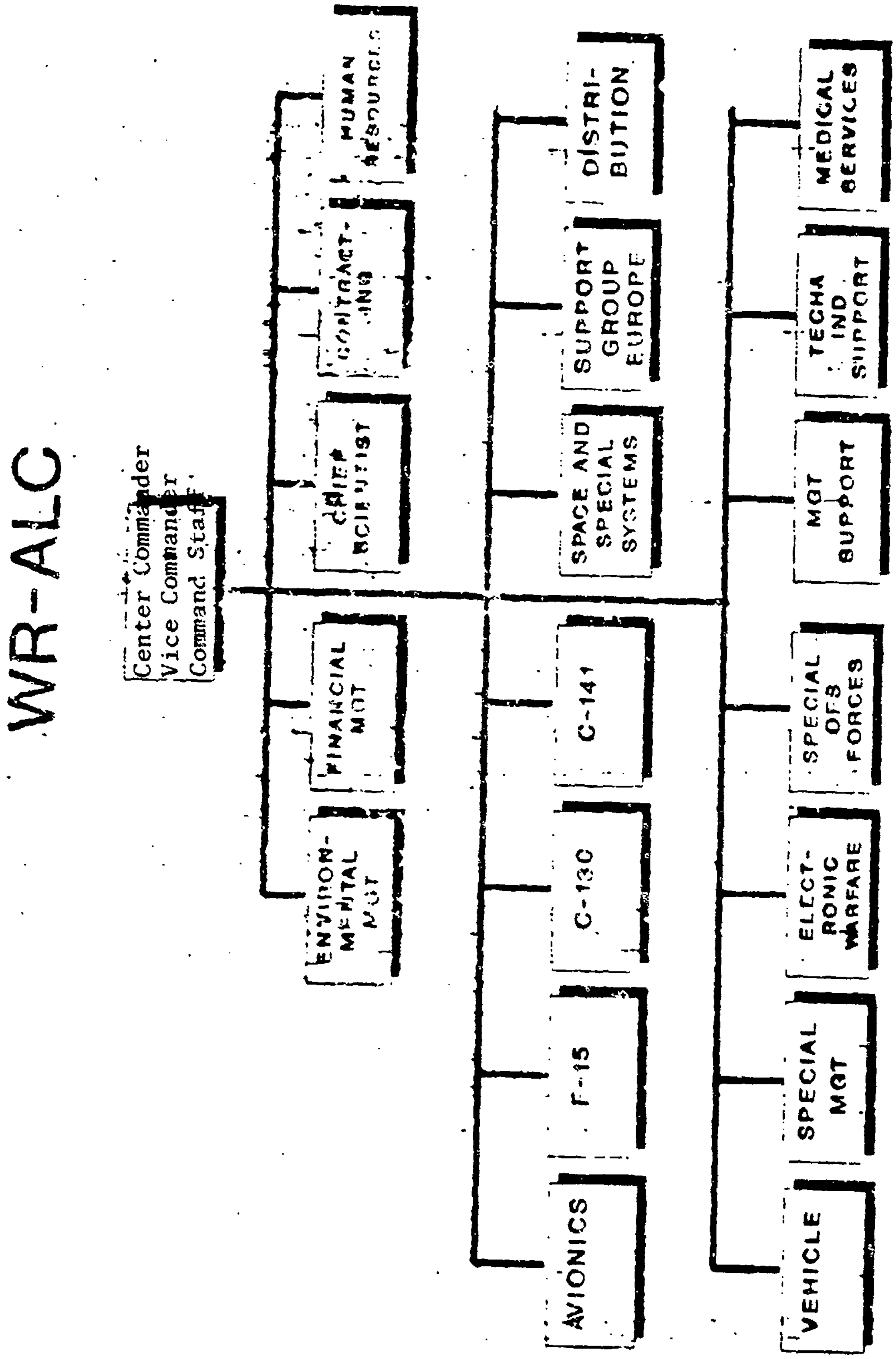


Figure IV-3. WR-ALC Organizational Chart

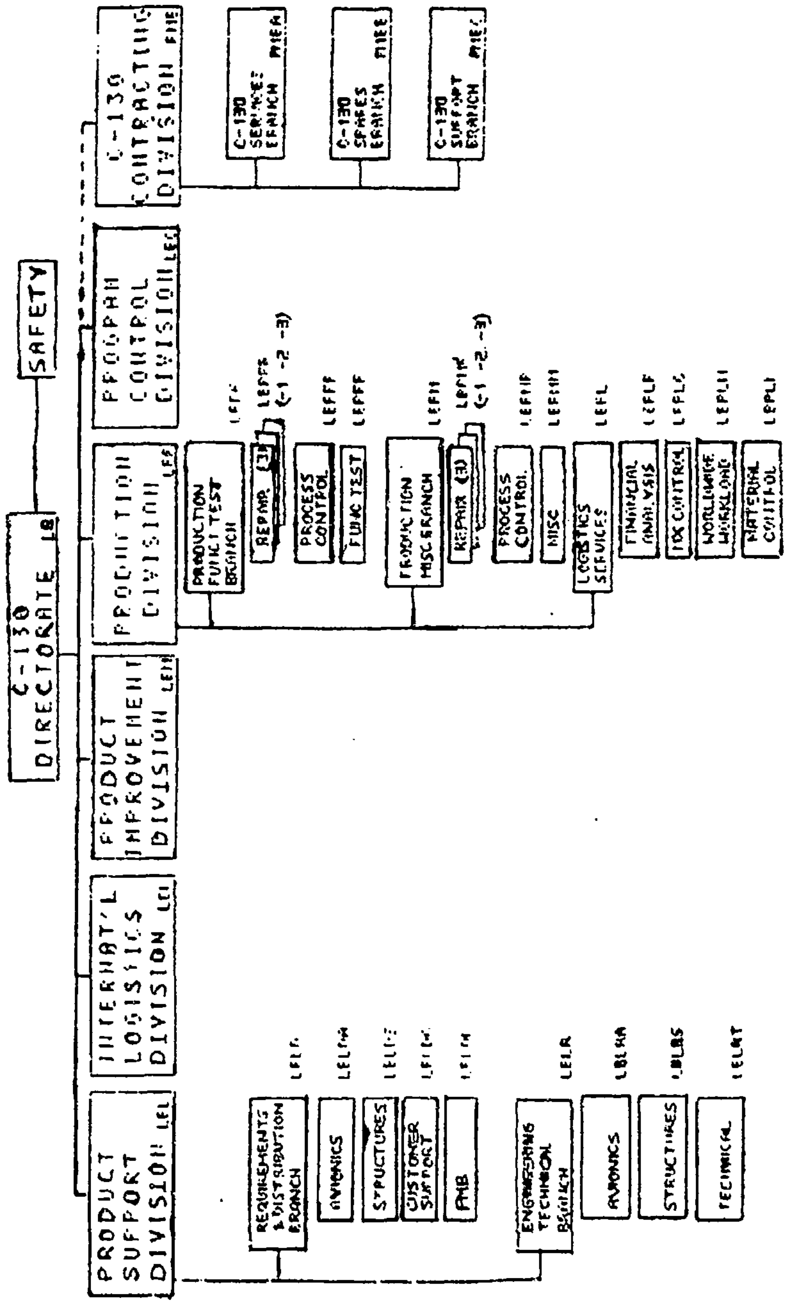
product directorates at WR-ALC are each responsible for managing the four AFLC core functions of logistics requirements, acquisition, distribution, and maintenance for their particular weapons system (Fry, 1989). Aircraft maintenance management now exists as a single division under each major product directorate (F-15, C-130, and C-141). By placing personnel in requirements, acquisition, and maintenance in the same chain of command, AFLC hopes to become more responsive to its customers (West, 1990).

C-130 Directorate Overview

Organization and Workload

While PDM for the Air Force's C-130 aircraft is performed at both OO-ALC and WR-ALC, system program management responsibility is located at WR-ALC. In other words, the director of the C-130 directorate at WR-ALC is responsible for providing requirements support and engineering/technical support for all C-130s in the Air Force. These functions fall under the product support division, which is one of the six divisions comprising the C-130 directorate organization shown in Figure IV-4. Slightly more than two-thirds of the directorate's 614 total personnel are employed in the production division, which is responsible for aircraft maintenance.

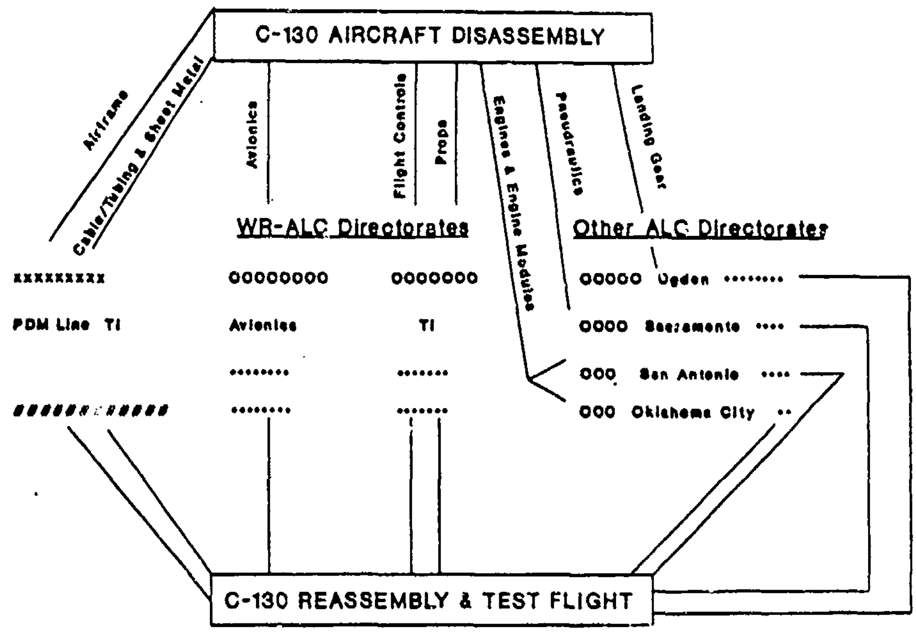
WR-ALC provides depot maintenance for approximately 30 percent of the Air Force's C-130 aircraft. In fiscal year (FY) 1991, 30 C-130s, averaging 131 flow days per aircraft,



<u>Figure IV-4</u>. C-130 Product Directorate Organizational Chart

were scheduled for PDM at this depot. Of the remaining 69 C-130s scheduled for PDM in FY 1991, 35 were to be overhauled at OO-ALC, 25 were to be repaired by PEMCO, a civilian contractor in Birmingham, Alabama, and 9 were to be routed to overseas depots in Italy and Malaysia. The number of aircraft to be overhauled during a fiscal year is planned two to three years in advance by AFLC and the operational commands. The operational commands estimate the number of C-130s that will require depot maintenance. Based upon a depot's projected availability of manpower and facilities, AFLC distributes this workload among the C-130 depot repair facilities.

Figure IV-5 provides an aggregated flow chart for C-130 depot maintenance at WR-ALC. This chart is also representative of the depot maintenance cycle for other types of aircraft at WR-ALC and at other ALCs. When a C-130 arrives at WR-ALC, it enters the PDM line's pre-dock, where it is defueled, dearmed, and inventoried. The aircraft then is towed to the mod-dock, where disassembly begins. The C-130 repair actions shown across the top of Figure IV-5 under disassembly have been arbitrarily divided into eight aircraft subsystems. This division closely parallels that shown on the C-130 PDM flow chart in Figure IV-9. As Figure IV-5 illustrates, these repair actions fall into three different categories - those which involve other ALCs (right-hand side of chart), those which involve other



xxxxx = Aircraft awaiting maintenance actions

= Inventory for miscellaneous parts that is present in bench stocks and central supply.

00000 = Items awaiting induction into the shops

***** = Finished goods inventory (items that have been repaired)

Figure IV-5. Aggregated Flow Chart for C-130 Depot Maintenance

directorates at WR-ALC (middle of chart), and those which are mainly performed by the C-130 directorate (left-hand side of chart). Airframe designates those repair actions performed by the C-130 production division on the PDM line, such as defueling, painting, and fuselage pressurization. The sheet metal branch, a branch in the Technology and Industrial Support Directorate (hereafter referred to as TI), is the only outside agency that performs work on the PDM line on a regular basis. It manufactures replacement cable and tubing and performs sheet metal repairs.

The directorates in the middle and right-hand portions of Figure IV-5 perform repairs for two major users - the PDM line and base maintenance units. As a rule, approximately 95 percent of the workload in these two portions of the chart is scheduled maintenance generated by MISTR (Maintenance Items Subject to Repair) program inputs. MISTR items are those component parts that cannot be repaired by base maintenance units and are sent directly to a particular ALC for depot-level repair. The remaining five percent of this workload consists of "job-routed" components that are removed from an aircraft on the PDM line, sent to a supporting directorate for repair, and returned to the PDM line. WR-ALC's TI directorate repairs C-130 flight control surfaces and propeller assemblies for all C-130s in the Air Force. The flow for the other four aircraft subsystems - avionics, engines, hydraulics, and landing gear - follows the Air Force's TRC concept and would be divided in the same

manner for other types of aircraft repaired at WR-ALC and at other ALCs.

Goals and Objectives

Although WR-ALC occasionally performs unscheduled maintenance on Army, Navy, and Coast Guard C-130s, virtually all of its customers are from the 7 Air Force, 15 Air Force Reserve, and 20 Air National Guard units shown in Figure IV-6. The goal of the C-130 directorate is to increase weapon system readiness by exceeding customer expectations through continuous improvement of the quality, timeliness, and total cost of logistics support. This goal reflects AFLC's emphasis on customer satisfaction and the implementation of QP4 [meaning quality = people + process + performance + product] (Baldwin, 1990), its program for total quality management (TQM).

The C-130 director lists safety, quality, and process improvement as his directorate's three most important objectives. He includes environmental safety and personal job safety in the safety objective and views safety as a necessary condition for accomplishing the other two objectives. The C-130 directorate's stated objectives are to remain competitive for its PDM workload and to develop product teams for improving the C-130. To remain competitive, the directorate has established the following subobjectives: sustain 30 PDMs annually; decrease C-130s on the ramp to 10; decrease PDM flow days to 100; reduce

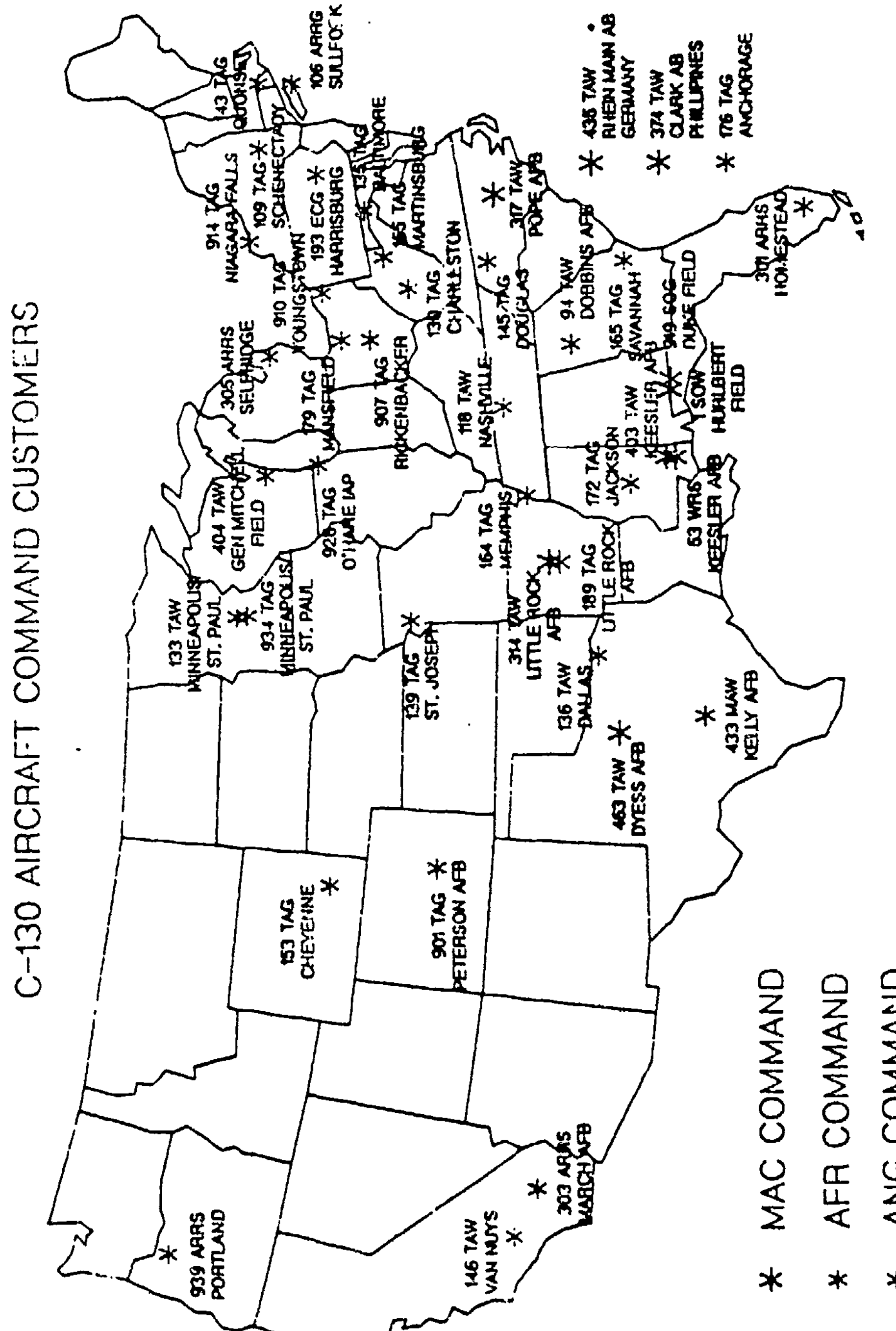


Figure IV-6. C-130 Product Directorate Customers

quality defects by ten percent; measure rework; break even in the DMIF (Depot Maintenance Industrial Fund); and improve special mission maintenance/mod capability. As part of the product team objective, the C-130 director has established a quarterly awards program to recognize "superstars", encourages everyone to be proud of their work, and wants to have all product team members trained in TQM by December, 1992. The product teams consists of engineers, equipment specialists, item managers, production management specialists, logistics officers, and maintenance personnel. These teams provide more timely and efficient support for a weapon system and have recently been implemented in various AFLC units.

Supporting Directorates

Because the C-130 aircraft is not an avionics-intensive airplane, the Avionics Directorate at WR-ALC was not considered to be a critical directorate for supporting C-130 depot maintenance. The Technology and Industrial Support Directorate, which overhauls C-130 propeller assemblies, manufactures C-130 cable and tubing, and does sheet metal work for the PDM line, was determined to be the most critical directorate for providing both commodity and structural repair support for the C-130. Consequently, the research for this case focused on the propeller and sheet metal branches. The head of the Special Systems Repair Division, the parent division for the propeller branch, was also interviewed. However, while there are other branches

and divisions in TI that support C-130 depot maintenance, none of these other areas was examined. Additionally, no other supporting directorates at WR-ALC, such as Avionics and Distribution, were looked at in this case study. A final limitation of this research concerns the fact that only C-130 depot maintenance at WR-ALC was examined. Therefore, the findings of this study may not be applicable to the C-130 depot maintenance operations at Ogden ALC (OO-ALC) and at various contractor facilities. Finally, although the research emphasis in the C-130 directorate was on the Production Division, discussions were also held with engineers and production management specialists in the Product Support and Product Improvement Divisions.

Technology and Industrial Support Directorate Overview

Organization and Workload

WR-ALC's Technology and Industrial Support Directorate, hereafter referred to as TI, is composed of eight divisions - special systems repair, manufacturing, component processing, component repair, structural repair, technology and engineering sciences, plant management, and program control. TI's standard operating hours are 7:30 a.m. to 4:15 p.m., Monday through Friday. For most divisions, including special systems repair, nearly all of the quarterly workload is scheduled maintenance generated by MISTR program inputs.

In contrast, nearly all of the quarterly workload in the manufacturing division's sheet metal branch is

unscheduled maintenance. Approximately 80 percent of that work is in support of the WR-ALC PDM line. The remaining 20 percent is to support customer requests from other ALCs or the depots of other military services. The sheet metal branch operates much more closely with equipment vendors and materials suppliers than do the other branches in TI or the C-130 production division. Even though funding is an ongoing problem, the branch is making a concerted effort to upgrade and replace much of its 1950's technology. The sheet metal Process Action Team (PAT), a TQM improvement team, was the first PAT formed at WR-ALC and continues to be a leader in initiating process improvements. Flow charts for the sheet metal and the cable and tubing processes are displayed in Figures IV-7 and IV-8.

PATs in the propeller branch have also been instrumental in solving problems related to defective barrel bolts and seal replacement. The C-130 propeller consists of three major subassemblies - the blades, the dome, and the barrel. Each quarter the propeller branch repairs an average of 80 C-130 propeller assemblies for the Air Force and 20 for the Navy. Propeller blade repair involves fourteen major operations - disassembly, non-destructive inspection, alignment, rubberizing, grinding, baking, contact ring installation, blade balancing, painting, final blade assembly, propeller buildup, propeller balancing, propeller final test, and propeller unit reassembly and repackaging.

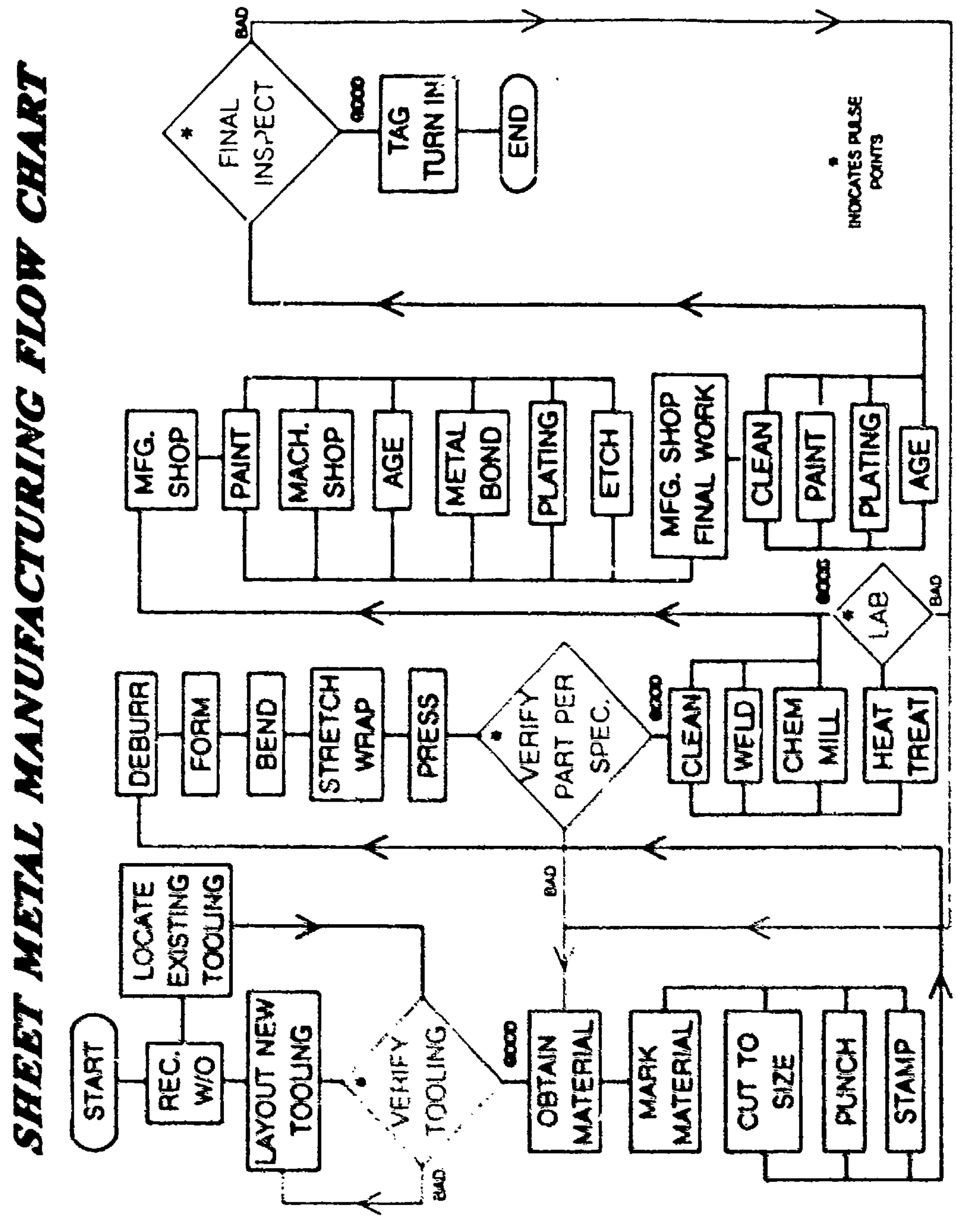


Figure IV-7. Sheet Metal Flow Chart

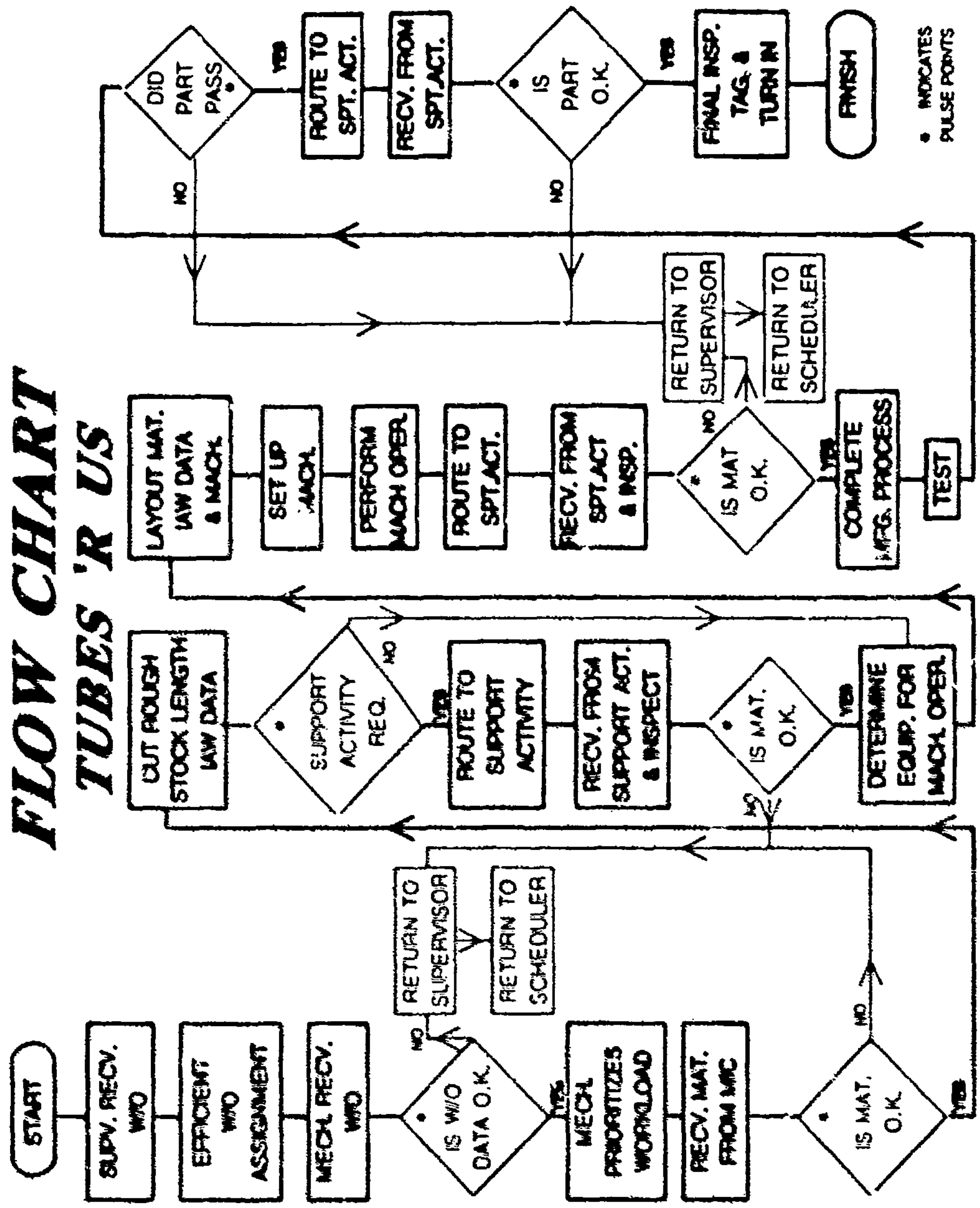


Figure IV-8. Cable and Tubing Flow Chart

TI Goals

TI's vision reflects the command's emphasis on customer satisfaction. The TI vision is "to exceed our customers' expectations by continuously improving the quality, timeliness, and total cost of the products and professional services we provide to enhance combat strength through a partnership with the customers, suppliers, workforce, community, and environment." The directorate's seven goals are as follows:

(1) Reduce production cost by 3 percent

(2) Ensure customer satisfaction through defect-free workmanship and delivery of products by need date

(3) Increase output per manday by 3 percent

(4) Decrease flow days for F-15 wings by 8 percent

(5) Assure quality products

(6) Streamline engineering/laboratory services to provide effective and timely support

(7) Improve the environment through zero hazardous waste disposal violations

C-130 Production Division Overview

Organization and Workload

The C-130 production division contains three branches - production/functional test, production/miscellaneous, and logistics services (refer to Figure IV-4). The division's direct workforce of 323 maintenance personnel is divided between the first two branches and works 10 hours per day, four days per week, either Sunday through Wednesday or

Wednesday through Saturday. The 95 indirect workers in logistics services and supervisory positions work Monday through Friday, 7:30 a.m. - 4:15 p.m. Logistics services includes such functions as financial analysis and workload planning.

Approximately 85 percent of WR-ALC's annual C-130 workload is PDM inputs that are planned in advance by owning commands. Scheduled modifications represent another 10 percent. The remaining five percent of the annual workload results from C-130s that "drop-in" for unscheduled repairs. Even though 95 percent of the total workload is planned, the actual repairs which must be performed on any individual aircraft vary tremendously. Furthermore, in any one year WR-ALC may receive as many as 21 different types of C-130s, each with its own unique parts and overhaul requirements. This variable, coupled with the fact that 60 percent of C-130 airframe maintenance is performed outdoors, adds considerable uncertainty to an already unpredictable process.

PDM Flow

The flow for the C-130 PDM process outlined in Figure IV-9 is divided into three major phases - pre-dock, mod-dock, and post-dock. Pre-dock involves checking the maintenance records to determine the aircraft's condition and the inspections and repairs required. Although this phase is where the aircraft is defueled, dearmed, and

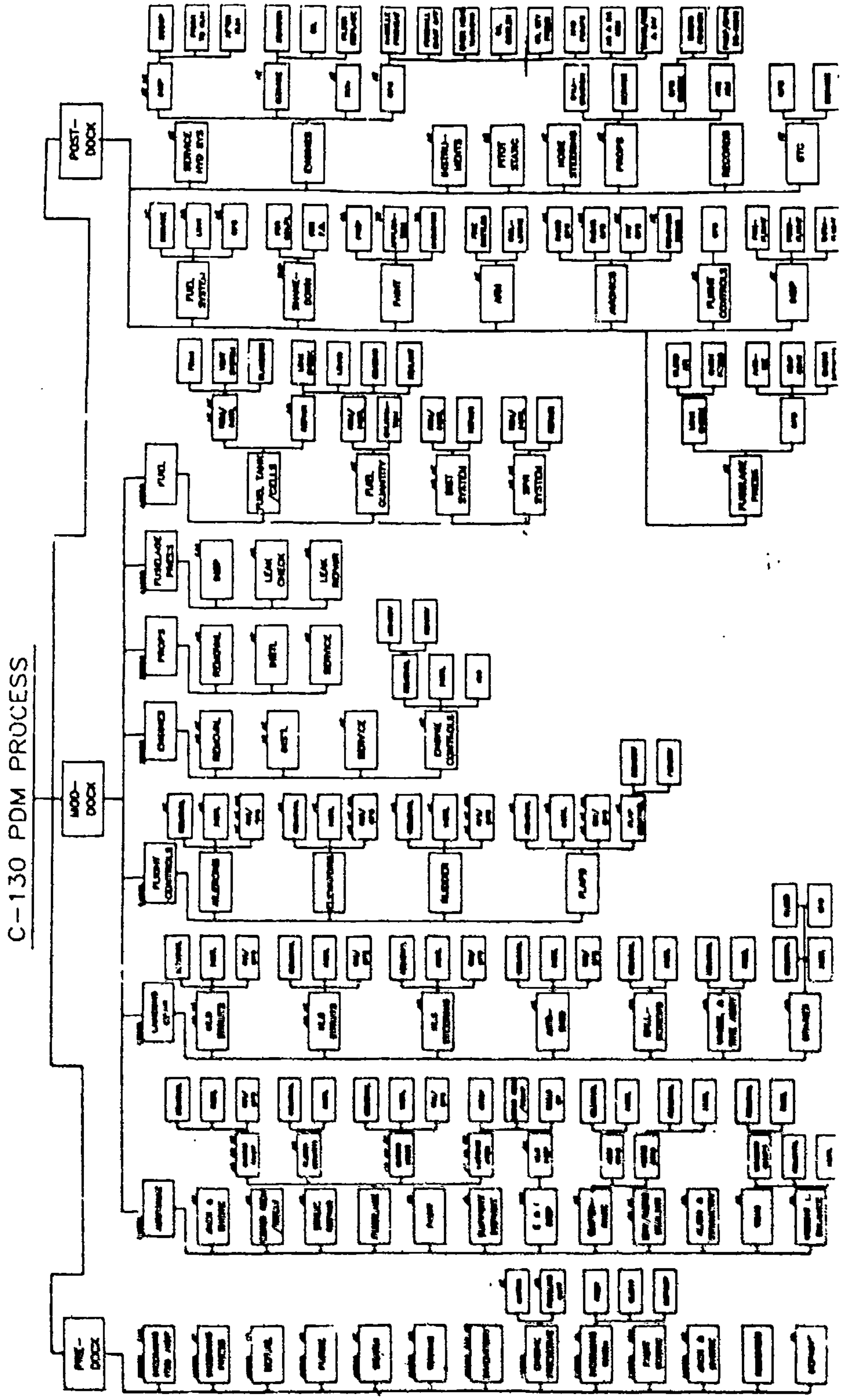


Figure IV-9. C-130 PDM Flow Chart

depainted, actual teardown does not occur until the aircraft is moved to the mod-dock. As Figure IV-9 illustrates, the disassembly and reassembly of a C-130 involves the removal, inspection/repair, and installation of components in seven major systems - airframe, landing gear, flight controls, engines, props, fuselage pressurization, and fuel. Final operational checks and functional test flights are conducted at post-dock.

To appreciate the complexity of AFLC depot maintenance, the PDM process in Figure IV-9 needs to be viewed simultaneously with the Air Force logistics chart in Figure IV-1 and the C-130 depot maintenance flow chart in Figure IV-5. The replacement of one component for the flight controls system will be used as an example to highlight some of the interactions involved in the AFLC depot maintenance cycle. When a worker on the PDM line determines that an aileron actuator on a C-130 must be replaced, he orders that particular model of aileron actuator from central supply at WR-ALC. If central supply at WR-ALC has that model in stock, they issue it to the PDM line and the mechanic installs it on the aircraft. If the WR-ALC central supply does not have that particular actuator in stock, they must obtain it from central supply at SM-ALC, the TRC for hydraulic components, or from a base supply at a C-130 operational unit. If the part is not available from these sources and cannot be obtained in time to prevent work stoppage on the PDM line, the PDM line chief will generally

try to cannibalize the model of aileron actuator needed from another C-130 aircraft with a later customer due date.

Mission

The above example illustrates some of the difficulties encountered in providing customers at operational units with timely delivery of quality aircraft. The mission of the C-130 production division is to perform C-130 aircraft maintenance which is cost effective and provides world class quality in a timely manner while continuing process improvement. To better understand how the C-130 production division accomplishes this mission, it is necessary to identify the performance criteria currently being used by the C-130 and TI directorates, as well as the constraints to continuous improvement that exist in these organizations. Thus, the remainder of this case will address the last three research questions in this dissertation according to the following topics: competitive edges, performance criteria, and system constraints.

Competitive Edges

Directorate and Division Rankings

Because DOD is now encouraging competition among the depots of all military services, this dissertation will assess the importance of using competitive edges commonly employed in private industry as a basis for an AFLC performance measurement system. Lockamy (1991) had representatives from six world class manufacturing firms evaluate the importance of the competitive advantages of

cost, quality, due date performance (delivery), lead time, product/process flexibility, and product/process innovation. The C-130 director and selected division and branch chiefs from the C-130 and TI directorates were asked to rank how critical these six competitive advantages, or edges, are for accomplishing C-130 depot maintenance. A rank of 1 denoted the most critical competitive edge, while a rank of 6 indicated that the competitive edge was least important. Two sets of rankings, one based on a unit's stated goals and objectives and the other upon the performance criteria by which that unit's performance is evaluated, were obtained.

Figure IV-10 provides the C-130 and TI directors' rankings for the competitive edges. The C-130 director considers safety to be a part of the quality element. The rankings of these two directors exhibit much more similarity in the performance criteria category than in the objectives category. The C-130 director believes that his organization must be flexible and innovative if it is to reduce production costs and achieve its schedule (delivery) objectives. The division chiefs of the C-130 production division and TI's manufacturing and special systems repair divisions also evaluated the six competitive edges. Their rankings are reported in Figure IV-11. Except for the reversal of the cost and delivery rankings in the objectives category, the rankings of the C-130 production and TI special systems repair division chiefs are identical. The

C-130 Directorate (n=1)		
Rank Order	By Objectives	By Criteria
1	Quality	Cost
2	Flexibility	Delivery
3	Innovation	Quality
4	Cost	Flexibility
5	Delivery	Innovation
6	Lead Time	Lead Time

TI Directorate (n=1)		
Rank Order	By Objectives	By Criteria
1	Quality	Delivery
2	Cost	Cost
3	Delivery	Quality
4	Lead Time	Flexibility
5	Flexibility	Lead Time
6	Innovation	Innovation

Figure IV-10. Directorate Competitive Edge Rankings

C-130 Production Division (n=1)		
Rank Order	By Objectives	By Criteria
1	Quality	Quality
2	Cost	Delivery
3	Delivery	Cost
4	Lead Time	Lead Time
5	Flexibility	Flexibility
6	Innovation	Innovation

TI Manufacturing Division (n=1)		
Rank Order	By Objectives	By Criteria
1	Innovation	Innovation
2	Quality	Quality
3	Delivery	Cost
4	Flexibility	Delivery
5	Lead Time	Flexibility
6	Cost	Lead Time

TI Special Systems Repair Division (n=1)		
Rank Order	By Objectives	By Criteria
1	Quality	Quality
2	Delivery	Delivery
3	Cost	Cost
4	Lead Time	Lead Time
5	Flexibility	Flexibility
6	Innovation	Innovation

Figure IV-11. Division Competitive Edge Rankings

TI manufacturing chief, however, ranked innovation as the most critical, rather than the least critical, competitive edge. This division chief considers outdated technology to be a major constraint in his shops, so it is not surprising that he ranked innovation as the most important edge.

Branch and First-line Supervisor Rankings

Three branch chiefs in the TI directorate and all three branch chiefs in the C-130 production division evaluated the six competitive edges. Their rankings have been averaged and are reported in Figure IV-12. The rankings of the TI branch chiefs displayed a much higher agreement than those of the C-130 production division. In both the objectives and criteria categories, all three TI branch chiefs said that quality, cost, and delivery were the three competitive edges most critical for mission accomplishment. Two of the branches ranked innovation, lead time, and flexibility as the fourth, fifth, and sixth most important edges. The third branch chief rated flexibility, innovation, and lead time as the least important competitive edges, in that order.

Although there was less consistency in the rankings of the branch chiefs in the C-130 production division, the rankings of the two production branch chiefs were quite similar. These two individuals rated lead time, flexibility, and innovation as the least critical competitive edges on the basis of both unit objectives and

C-130 Production Branches (n=3)				
Rank Order	By Objectives	Ranking	By Criteria	Ranking
1	Quality	1.00	Quality	1.67
2	Delivery	2.33	Delivery	2.00
3	Cost	3.00	Cost	2.33
4	Lead Time	4.67	Lead Time	4.67
5	Flexibility	5.00	Flexibility	5.00
6	Innovation	5.33	Innovation	5.33

TI Branches (n=3)				
Rank Order	By Objectives	Ranking	By Criteria	Ranking
1	Quality	1.00	Quality	1.00
2	Cost	2.00	Cost	2.00
3	Delivery	3.00	Delivery	3.00
4	Innovation	4.33	Innovation	4.33
5	Lead Time	5.33	Lead Time	5.33
6	Flexibility	5.33	Flexibility	5.33

Figure IV-12. Competitive Edge Rankings at Branch Level

performance criteria. Likewise, by objectives and by criteria, quality was ranked most important. The logistics branch chief ranked quality as the most important objective but as only the third most critical criterion. On the basis of both objectives and criteria, he deemed innovation, flexibility, and lead time to be the least important competitive edges.

Like all branch chiefs, on the basis of both objectives and criteria, TI first-line supervisors ranked quality, cost, and delivery to be among the top three competitive edges. However, the C-130 first-line production supervisors considered quality, delivery, and lead time to be the three most important edges. Cost was ranked as the fourth most critical edge on the basis of both objectives and criteria. The fact that C-130 first-line production supervisors tend to be held responsible for aircraft meeting AMREP due dates may explain why these individuals believed lead time to be more critical than cost. On the basis of objectives and criteria, both groups of first-line supervisors regarded flexibility and innovation to be the least important edges. The first-line supervisor rankings are reported in Figure IV-13.

Performance Criteria

DOD and AFLC Performance Criteria

Traditionally, AFLC maintenance functions have been measured by efficiency criteria (e.g., output per paid

C-130 Production First-Line Supervisors (n=3)				
Rank Order	By Objectives	Ranking	By Criteria	Ranking
1	Quality	1.67	Quality	1.67
2	Delivery	1.67	Delivery	2.67
3	Lead Time	2.67	Lead Time	3.00
4	Cost	4.00	Cost	3.67
5	Flexibility	5.33	Flexibility	5.67
6	Innovation	6.33*	Innovation	6.00

TI First-Line Supervisors (n=3)				
Rank Order	By Objectives	Ranking	By Criteria	Ranking
1	Quality	1.00	Quality	1.33
2	Delivery	2.33	Cost	2.00
3	Cost	3.67	Delivery	2.67
4	Lead Time	3.67	Lead Time	4.00
5	Flexibility	5.00	Flexibility	5.33
6	Innovation	5.33	Innovation	5.67

*One first-line supervisor ranked effectivity #5, by objectives; and #2, by criteria. As a result, he ranked innovation #7, by objectives; and flexibility #7, by criteria.

Figure IV-13. Competitive Edge Rankings by First-Line Supervisors

manday and labor effectiveness), and AFLC requirements functions have been evaluated on the basis of program execution and MICAP (Mission Capable) hours. Prior to 1991, AFLC's performance measurement system was patterned after the objectives matrix developed at Oregon State University (Felix & Riggs, 1983). The AFLC matrix was composed of three broad categories of criteria - resources, production/timeliness, and quality/customer satisfaction - and several subcategories which were all allocated particular weights. For example, total weight for resources was 34, and financial measures were allocated 16 percent of resource weight. Criteria from this matrix which apply to WR-ALC are shown in Figure IV-14.

In the last few years the DOD depot maintenance community has realized that their performance measurement systems are outmoded. Accordingly, the Defense Depot Maintenance Council (DDMC) recently developed a new performance measurement system, called the Defense Depot Performance Measurement System (DDPMS), for use by all DOD depots (refer to Figure IV-15). The DDPMS was fully implemented by October, 1991. The criteria for this system fall under three major categories - timeliness, cost, and quality. Since the DDPMS criteria were first proposed, two critical events have occurred. The new product directorate reorganization has taken place, and the decision to stock fund depot reparables has been made. This decision requires customers from operational units to purchase depot

I. Production/Timeliness Category (Total Weight = 33)

Aircraft Production

1. Requirement - Percent aircraft produced versus requirement.

2. Initial AMREP (Aircraft/Missile Maintenance Production Compression Report) Schedule - Percent aircraft produced versus number initially scheduled for month.

3. Flow Days - Variance between actual flow days and average not to exceed date for aircraft produced during a reporting period.

<u>MISTR Production in Hours</u>

1. Requirement - Percent MISTR production hours versus initial requirement.

2. Initial Negotiation - Percent MISTR production hours compared to initial negotiated hours.

<u>MISTR Production in Units</u>

1. Requirement - Percent units produced compared to initial requirements.

2. Initial Negotiation Unit - Percent units produced compared to initial negotiations.

II. Quality/Customer Satisfaction Category (Total Weight = 33)

1. Aircraft Defect Rate - Number of customer reported defects (major and critical) per 10,000 aircraft production hours.

2. MISTR Defect Rate - Number of defective units per 10,000 production hours.

<u>Figure IV-14</u>. AFLC Performance Criteria

III. Resource Category (Total Weight = 34)

People Measures (12 percent of resource weight)

1. Manpower Utilization - Number of permanently assigned versus the number of permanently authorized.

2. Cost of Mishaps - Total cost of maintenance mishaps per 200,000 production hours.

3. Number of Mishaps - Total number of maintenance mishaps.

4. Output per Paid Manday (OPMD) = (DPSH/Total paid hours) x 8 hours per day; [DPSH = Direct Product Standard Hours]

5. Environmental Differential Pay (EDP) - Measures actual EDP cost per 200,000 production hours.

Financial Measures (16 percent of resource weight)

1. Direct Labor Cost - Direct labor cost per DPSHs produced.

2. Overhead Cost - Overhead cost per DPSHs produced.

3. Material Cost - Material cost per DPSHs produced.

4. All Other Costs - All other costs per DPSHs produced.

5. Revenue Variance - Total Revenue row, Variance Percent column.

6. Net Operating Results - Operating Results, Organic Row Variance column divided by Total Revenue Actual column.

Equipment and Facilities (6 percent of resource weight)

1. Asset Capitalization Program (ACP) Obligation for PACER UPHOLD-Measures ACP obligations for PACER UPHOLD (current year).

2. Preventive Maintenance (PM) = PM completed/PM required x 100

3. Energy Consumed - Measures the cost (in cents) of energy used for each dollar received in organic sales.

Figure IV-14. AFLC Performance Criteria

Effectiveness

Scheduled Conformance = Scheduled units completed on time/Units scheduled

Efficiency

Direct Labor Utilization = Direct labor hours earned/Direct labor hours used x 100%

Direct Material Utilization = Direct material planned/Direct material used x 100%

Quality

Cost of Quality = Cost of quality/Total cost x 100%

Conformance/Non-conformance Ratio = Cost of conformance/Cost of non-conformance

Capacity Utilization

Peacetime Utilization Index = Funded workload/Capacity index

Mission Utilization Index = Executable requirements/Capacity index

[Capacity Index = (Work Positions) x (Availability Factor) x (Annual Productive Hours)]

Productivity

Productivity Index = Base period cost/Base period quantity

Cost Performance

Cost Performance = Revenue earned/Cost of goods sold

Innovation

Innovation - Qualitative narrative summarizing the technical and management innovations implemented during the reporting period

Figure IV-15. DDPMS Performance Criteria

reparables from the Reparable Support Division (RSD) stock fund. As a result, some WR-ALC directorate presidents believe that the DDPMS criteria should be reexamined and possibly replaced with Goldratt and Fox's (1986, 1988) global criteria of throughput (T), inventory (I), and operating expense (OE) and a fourth criterion, quality (Q) (Gillis, March 22, 1991).

WR-ALC and Directorate Performance Criteria

As can be seen from Figure IV-16, financial management topics and cost criteria dominate the monthly WR-ALC Management Review briefing. In a recent WR-ALC Review, the first three slides addressed sick leave trends, direct labor effectiveness, and output per paid manday (OPMD) - all labor efficiency criteria. The remaining 18 charts discussed operating results, broken down into revenues and expenses, and analyzed WIP.

In contrast, the C-130 Product Directorate Monthly Management Review is divided into five major areas - mission support, customer support, production, financial management, and special interest items. Traditional production criteria like OPMD are still mentioned, but just as much weight is given to engineering and contracting criteria. Criteria and topics from a recent C-130 directorate management review are provided in Figure IV-17.

Criteria from the TI Monthly Management Review are shown in Figure IV-18. This briefing begins with an

1. Sick Leave Trends - Sick leave as percent of regular paid hours

2. Direct Labor Effectiveness - Ratio of direct product earned hours (DPEH) to direct product actual hours (DPAH)

3. Output per Manday = (DPSH/Total paid hours) x 8 hours/day

4. WR-ALC Organic Operating Results - Listing of WR-ALC's revenue, cost of goods sold, and profit/loss for the current fiscal year by actual, target, and variance categories

5. WR-ALC Revenue - Listing of WR-ALC's actual, target, and variance revenue by five categories: aircraft, exchangeables, software, other, and total

6. WR-ALC Profit/Loss (P/L) - Listing of WR-ALC's actual, target, and variance P/L by five categories: aircraft, exchangeables, software, other, and total

7. WR-ALC Organic Total Expenses - WR-ALC's actual, target, and variance expenses by labor, material, other, and total categories

8. WIP Analysis Summary - DPEH and money in WIP by aircraft, exchangeables, software, local manufacture, and total categories

9. Cost in WIP Rate - WIP rate cost by actual, target, and variance categories for the latest four months

10. Total Money in WIP - Total money in WIP by labor, material, other, unallocated cost, and total categories

11. Monthly and Cumulative Product Directorate Organic Operating Results - Operating results for each of six depot maintenance directorates for the latest month and for the fiscal year-to-date

12. Profit/Loss Analysis Status - Bullets on OO-ALC/WR-ALC efforts

<u>Figure IV-16</u>. WR-ALC Management Indicators

1. AF Customers - C-130 aircraft inventory by command

2. Aircraft Readiness - C-130 mission capable, not mission capable supply, and not mission capable maintenance rates

3. MICAP Hours by ALC - Number of hours C-130 aircraft are grounded for lack of parts, by each ALC responsible for those items

4. Cann Actions - Number of cannibalization actions by ALC

5. WRM Actions - Number of withdrawals from War Reserve Material (WRM) supply stock, by ALC

6. Top Five Problem Items - Five items with highest MICAP hours

7. Top 20 Inapplicable - Top 20 items, by dollar value, in excess inventory

8. Personnel - Number of people in direct, indirect, and overhead labor categories

9. Safety - Number of days/Time lost and first aid cases

10. Sick Leave Trend - Sick leave as percent of regular paid hours

11. Direct Overtime - Direct overtime as percent of DPAH

12. QP4 Training Status - Number of managers and workers trained and requiring training in TQM

13. AFTO Form 22 - Number of open tech data change requests

14. First Articles - Number of delinquent and on-time approvals for first articles for engineering modification programs

15. AFLC Form 103 - Average number of days to comply with engineering change requests

16. Contract Processing Time - Number of contracts and number of contract processing days required

17. Undefinitized Actions - Percent of delinquent C-130 contracts

18. PRs in Process - Number of purchase requests in process

Figure IV-17. C-130 Product Directorate Indicators

19. Competitive Dollars - Percentage of contract dollars awarded competitively

20. Contractor Protests - Number of protests

21. Depot Aircraft Inventory - C-130 depot maintenance inventory at all locations

22. Worldwide Aircraft Output - C-130 depot maintenance production

23. PDM Flow Days - Average number of flow days at all locations

24. Effectiveness - Direct labor effectiveness for C-130 production

25. Output per Manday - OPMD for C-130 production

26. Defects per Aircraft - Average number of defects per aircraft

27. Fiscal Year to Date - C-130 Directorate's Profit/Loss statement

28. DPEM Aircraft Program - Money obligated, fiscal year-to-date, for the depot purchased equipment maintenance (DPEM) program

29. Contract DMIF Program Execution - Money spent, fiscal year-to-date, for the contract DMIF program

30. C-130 Contract DMIF Revenue - Contract DMIF revenue, fiscal year-to-date, for aircraft and exchangeable categories

31. 3400 Funds - Money authorized and committed for sustaining engineering and the modification of exchangeables

32. 3400 Funds - Money authorized and obligated for software, interim contractor support, and contractor logistics support

33. BP 3400 - Funds authorized and obligated for the C-130 Directorate Operations and Maintenance Fund

Figure IV-17. C-130 Product Directorate Indicators

1. Profit/Loss YTD - TI profit/loss statement, fiscal year-to-date

2. Workman's Compensation - Number of workers paid workman's compensation, fiscal year-to-date

3. Sick Leave - Sick leave as percent of regular paid hours

4. Overhead vs Direct - Number of people in these labor categories

5. Accidents/Lost Time - Number of accidents and days of lost time

6. Overtime - Direct overtime as a percent of DPAH

7. DMIF Minor Construction/Equipment - Funds allocated and obligated for minor construction and equipment in TI

8. O & M Funds - Money allocated and obligated for the operations and maintenance fund

9. DPEM Funds Status - Money allocated and obligated for DPEM

10. Sustaining Engineering - Money allocated and obligated for sustaining engineering

11. BP 12 Funds - Money allocated and obligated for common ground support equipment

12. BP 84 Funds - Money allocated and obligated for other base maintenance and support equipment

13. Critical Items - See text for definition

14. Routed Items - On-time and late delivery statistics for routed items for the latest month

15. Quality Deficiency Reports (QDRs) & Evaluations - Descriptions of QDRs received from customers and evaluations of these reports

16. Output per Manday - Previously defined

17. F-15 Wing Flow Days - Flow days required to repair F-15 wings

<u>Figure IV-18</u>. TI Directorate Management Indicators

18. TQM Implementation - Number of TQM work center teams established

19. TQM Training - Percent of managers and workers trained in TQM

20. Conformance Verification Program - Narrative on program status

21. First Article Evaluation - Average days to process and evaluate first articles for modification projects

22. Environmental - Description of efforts to minimize waste and improve hazardous waste disposal

Figure IV-18. TI Directorate Management Indicators

overview of the directorate's vision and goals and follows with slides which present performance information related to each of those goals. Forty percent of the briefing addresses the production cost goal. Nearly all of the briefing's charts are in the form of numerical tables and/or narrative bullets.

Division and Branch Performance Criteria

As a rule, division and branch-level performance measurement systems are less concerned with financial indicators and tend to concentrate on only a few criteria, such as flow days, OPMD, and QDR (Quality Deficiency Report) rates. In TI's branches the key criteria used to evaluate performance are QDR rates, direct labor effectiveness, and critical item status. Item managers in the C-130 product support division determine which of their items have accumulated the most MICAP hours and provide this information to TI. TI's branches brief their divisions weekly on the status of these items. For each item, the following information is addressed: number negotiated for the quarter, number produced in the quarter, percentage of work completed (number produced /number negotiated), number of open work orders, number awaiting parts, and number of MICAP requisitions. In the C-130 production division's two production branches, flow days, rather than critical items, are the primary concern. These branches also track direct labor effectiveness and defects per aircraft.

At division level, labor efficiency accounts for 25 percent of the C-130 production division's monthly management review. Another 25 percent is devoted to financial management. The remaining 50 percent covers quality topics, flight test activity, and various trends concerning overtime, sick leave, and injuries. Quality is positively addressed by looking at the number of defect-free aircraft, instead of the number of defects per aircraft. This briefing emphasizes trends and contains a number of bar charts and graphs. It opens with an overview chart that shows the status of the division's four broad strategies (quality, safety/environment, cost, and schedule) and 16 specific strategies. The specific strategies are simply very general one or two-word phrases. Figure IV-19 summarizes the items addressed in this briefing.

System Constraints

Overview

The constraints present in the C-130 depot maintenance environment will now be examined and classified under four categories: physical, behavioral, managerial, and logistical. A fifth category, market constraints, exists in certain areas of the Air Force logistics system, especially as aircraft like the F-111 and A-10 are phased out of the active inventory. However, supervisors in the C-130 and TI directorates at WR-ALC indicated that, due to the unavailability of repair money, they increasingly must refuse C-130 workloads.

1. C-130 Strategy Overview Chart - Status of four primary strategies (quality, cost, schedule, and safety/ environment) and sixteen specific strategies (facilities, equipment, workload, parts, tools, tech data, documentation, management philosophy, leadership development, accountability, identification with customers, training, process improvement, management control systems, systems and procedures, and zero discharge)
2. Flow Day Progress - Actual and cumulative PDM flow days
3. Direct Overtime - Actual and budgeted direct overtime as a percentage of DPAH
4. Sick Leave - Sick leave as a percent of regular paid hours
5. Injury Trend - Number of injuries and days lost by month
6. C-130 Segmented Audit Defects - Aircraft defects by categories
7. C-130 Flight Test Activity - Description of recent activity
8. C-130 Functional Check Flights (FCFs) - Number of FCFs performed on each aircraft

Figure IV-19. C-130 Production Division Management Indicators

9. C-130 Defect-free Aircraft - Percent of aircraft produced each month that were free of defects
10. Division and Repair Unit Financial Status - Division and repair unit operating results (budget, actual, and variance) by six categories: labor, material, other, overhead, administrative, and total
11. Division and Unit Effectiveness - Direct labor effectiveness for the division and the repair units
12. Output per Manday - OPMD for the division (previously defined)

Figure IV-19. C-130 Production Division Management Indicators

Other researchers, such as Umble and Srikanth (1990), have identified two additional categories of constraints - material and capacity. In this researcher's opinion, these types of constraints typically result from managerial policies or constraints in the logistical system. Thus, for the purposes of this study, material and capacity constraints will be discussed in conjunction with managerial and logistical constraints, the two primary kinds of constraints found in the C-130 depot maintenance environment. In addition, barriers to improving system performance are present in the workforce and the physical layout of the facilities. However, these constraints do not appear to be as detrimental to overall system performance as those in the former two categories.

Physical Constraints

Supervisors in the TI directorate's sheet metal and propeller branches seem to have their operations laid out in a manner which logically corresponds to their product network flows. In the propeller shop, moving the blade alignment operation closer to blade grinding might be helpful but would probably make little difference in reducing the 14-day and 21-day flow times for Air Force and Navy propeller assemblies. The prop team A supervisor indicated that he would like more floor space, but lack of space is not the real issue. As the number of propeller assemblies in work usually averages 60, reducing the work-

in-process (WIP) in the system would easily solve the space problem.

Until recently, lack of sufficient indoor repair space was a legitimate problem for the C-130 production division. Formerly, the only indoor area at WR-ALC allocated to C-130 maintenance was the west dock of building 110, which could hold four C-130s. However, space was so limited at this dock that only one C-130 aircraft at a time could be moved. In addition, seven spots on the outdoor parking ramp and one slot in the nose dock in building 55 were assigned to C-130s. With 60 percent of C-130 maintenance previously performed outside, weather delays due to wind, rain, and lightning were a factor in missing customer due dates. Fortunately, this deficiency has been remedied with the completion of the Combat Talon facility in August, 1991. This new hangar has eight independent positions for jacking and shoring C-130 aircraft. With the Combat Talon hangar, indoor space to accommodate all C-130s on station at WR-ALC should be sufficient. Thus, weather will no longer have to be considered in determining aircraft flow days.

Another facility that should help the C-130 directorate meet its goal of 100 flow days is the new C-130 corrosion control hangar. Previously, all three types of aircraft repaired at WR-ALC - C-130s, C-141s, and F-15s - shared a single facility for painting (building 89) and one hangar for depainting (building 54). Because these two hangars are managed by the C-141 directorate, C-130 and F-15 aircraft

are sometimes delayed getting into either facility. The C-130 corrosion control hangar is able to accommodate one aircraft at a time and should eliminate the paint/depaint operation as a constraint in C-130 depot maintenance.

Behavioral Constraints

While the construction of new hangars will substantially alleviate the physical constraints in the C-130 production division, the building of new mindsets in the civilian workforce is a much more difficult and lengthy undertaking. Even though TQM was implemented in AFLC in 1988, the C-130 director observed that many of the civilian supervisors and workers still believe that TQM is just another short-term program, rather than a permanent change in maintenance philosophy. Despite the fact that quality is ranked among the top three objectives by the commanders of AFLC, WR-ALC, and the C-130 directorate, the concept of efficiency remains deeply ingrained in the workforce.

The deputy chief of the Avionics Directorate at WR-ALC, points out that for the past 30 years workers and supervisors at all levels of depot maintenance have primarily been evaluated on their ability to attain monthly and quarterly efficiency goals. Although a number of directorate and division chiefs, including the C-130 director, are no longer interested in labor effectiveness, many branch chiefs, first-line supervisors, and workers still believe their jobs depend on achieving high departmental efficiencies. Labor effectiveness is still one

of the performance criteria reported to depot and command levels and one of the two or three indicators every branch chief interviewed by this researcher uses to measure branch performance. Moreover, labor effectiveness remains the primary criterion by which the job performance of all first-line supervisors is evaluated. Consequently, workers and first-line supervisors perceive efficiency, instead of quality, to be the prime maintenance driver.

Other behaviors which impact the C-130 directorate's ability to meet cost objectives are a lack of long-term thinking and the failure to properly document all work performed. The C-130 production division chief noted that maintenance personnel tend to look no farther ahead than a single shift in determining the tools and parts needed to accomplish repair tasks. They expect a large inventory of replacement parts to be available on an hour's notice. In addition, they are typically enthusiastic about performing actual repairs but lax about filling out the aircraft forms and paperwork for documenting these repairs. The C-130 production division chief admitted that it is difficult to motivate first-line supervisors to document all work done to fix an aircraft so that customers may be charged for it. This insufficient documentation is probably one of the factors contributing to the C-130 directorate's inability to break even during most months. Even though the C-130 production division is now stressing cost and quality, most PDM line workers still assume that their primary objective

is to produce aircraft on schedule. Historically, these workers have received the greatest rewards for meeting AMREP delivery due dates. With the center commander's emphasis on attaining 100 flow days for C-130 PDMs by the end of FY 1991, it is not surprising that most C-130 production division personnel perceive delivery to be the division's number one objective.

In work centers where management is not under as much pressure to meet flow days, quality and cost seem to receive a higher priority. For example, in the propeller branch monthly profit/loss sheets are posted in every shop. The sheet metal branch chief claims that he no longer has problems with first-line supervisors "cherry picking" work orders. He attributes this behavioral change to TQM's philosophy of continuous improvement.

Managerial Constraints

TQM has led to a number of methods and process improvements in C-130 depot maintenance, particularly in the TI directorate. Unfortunately, management policies, particularly DOD and AFLC policies, are one of the biggest barriers to sustaining TQM's success and improving the C-130 directorate's overall performance. These policies cover issues related to organizational structure, fiscal management, and personnel management. Every supervisor interviewed at WR-ALC in March, 1991, was concerned about just one personnel policy - the DOD hiring and promotions freeze that took effect October 1, 1990. Due to this

freeze, for an indefinite period no additional personnel can be hired and none can be promoted to fill any vacancies. The freeze, coupled with the early civilian retirement offered in November, 1990, and the civilian reduction in force during early 1991, has resulted in a young and inexperienced workforce. In addition, many middle management positions are being filled on a temporary basis by new or underqualified supervisors.

Besides making it difficult to fill critical positions, the freeze makes it impossible to fill shortages in critical skills like electrician and hydraulic mechanic. However, with the majority of cutbacks being levied on indirect labor, most vacancies are in such areas as planning, scheduling, and production control. The hiring freeze was cited by the propeller branch chief and the chiefs of the C-130 production and TI special systems repair divisions as their biggest constraint to mission accomplishment.

Another constraint that compounds the effects of the hiring freeze, the reductions in force (RIFs), and the early retirements is the product directorate organization that occurred in October, 1990. The C-130 director views this reorganization as his biggest constraint. Because of the reorganization, all the informal communication channels essential for day-to-day mission accomplishment have had to be redeveloped and reestablished. The C-130 director also points out that AFLC's reorganization has decentralized responsibility but not authority. WR-ALC has 17 company

(directorate) presidents and one CEO (the center commander). There is no chief of staff or anyone else between the 17 directors and the center commander. Consequently, issues formerly handled at the O-6 (colonel) level by the heads of the old material management and maintenance directorates must now be brought to the attention of the two-star general. Of course, everyone is reluctant to air their problems before the center commander, so issues that cross weapon systems boundaries (F-15, C-130, or C-141) now take much longer to resolve.

Although competition and decentralization are the buzzwords for weapon systems repair, ALC tool management programs are still centralized. The TI directorate runs the tool program for the entire 6,000-person maintenance complex at WR-ALC. According to the C-130 director, TI neither understands the needs of its customers nor is very responsive to them. Likewise, the General Services Administration (GSA) does not want to hear about tool problems either. As a result, the C-130 directorate experiences considerable difficulty attaining reasonably priced quality tools.

With defense budget reductions, new equipment is even harder to obtain than new tools. The special systems repair division chief and the sheet metal branch chief said lack of money for new equipment was their second most critical barrier to mission accomplishment. Much of the machinery in TI's shops is 30 or 40 years old. For TI to be truly

competitive with private contractors and other depots, this technology needs to be replaced and/or upgraded. In the past year the sheet metal branch has acquired a CNC tube bender, a stand-alone swedger, and an improved type of cutoff blade. The branch engineer estimates, however, that the rehabilitation of a hydro press and the acquisition of a five-axis water abrasive cutter, a fluid cell press, and a deburring machine could improve productivity by an additional 500 percent. Even though the deburring machine costs just $9,000 and has a payback of $5,000 per year, AFLC has slipped funding for this item from FY 1988 to FY 1993.

None of the supervisors in the C-130 and TI directorates mentioned contracting policies as one of their top three constraints. The sheet metal branch chief did complain, though, that items on order in his branch often got cancelled because his personnel were not familiar with procurement procedures. A branch chief in the C-130 product improvement division discussed AFLC labor rate policies. He said that the same labor rate is charged for all work at any one depot (ALC) and that approval to adjust this rate must be obtained from AFLC headquarters. He believes that the center commander should have the authority to establish labor rates and that a different rate should be set for each weapon system (F-15, C-130, and C-141).

A major policy change concerns the stock funding of exchangeables (depot level reparables). As of October 1, 1992, logistics customers from the operational units will be

required to purchase serviceable exchangeable assets from the Reparable Support Division (RSD) stock fund (Lewandowski, 1991). Hence, as Falldine (March, 1991) has already pointed out to the ALC commanders, the ultimate solvency of directorates that repair exchangeables will hinge on sales from the RSD stock fund. Falldine also notes that DMIF budgets are constrained by factors not found in the private sector. These factors include stabilized prices, zero profit/loss goals, OSD/OMB (Office of the Secretary of Defense/Office of Management and Budget) directed inflation rates, and development which must be locked in two years prior to execution. Budget development is part of the Planning, Programming, and Budgeting System (PPBS), DOD's resource management system. Figure IV-20, adapted from a recent primer on the PPBS (DCS Programs & Resources, January 1987), illustrates how one PPBS cycle can total three years. Planning occurs during the first year, and programming actions take place during the second year. Finally, the Congressional action phase, where budget enactment and execution occurs, normally takes nine months.

While civilian contractors may change the prices they charge for products and services as often as monthly or weekly, Congressional law does not allow DOD depot prices to be adjusted any more frequently than once every two years. Several other laws enacted in recent years require that government contracts be adequately competed and that

PPBS SEQUENCE OF EVENTS

Here is the general time sequencing of key events within the PPBS (for FY 88 President's Budget)

- Air Force planners started work in August 1985. They are developing items for internal Air Force use and provide inputs to the Joint Strategic Planning Document and the Defense Guidance
- The Defense Guidance is issued to the Services and the Joint Staff and reflects the SecDef's policy, strategy, force planning, resource planning, and fiscal guidance in January 1986
- POM development is the intensive process by which the Services prioritize fiscally-constrained program proposals for the next five years
- Issue Papers prepared by members of the DRB to suggest program changes to the Service POMs. The DRB is the forum which reviews and provides recommendations to the SecDef on these proposed changes to the Services' programs
- The Program Decision Memorandum (PDM) records SecDef decisions on the issues and directs adjustments to the Service POM
  - The Budget Estimate Submission (BES) is the Service's budget proposal. The BES is based on the OSD review of the Service POM, as updated by the PDM
- OSD and the Office of Management and Budget (OMB) hold hearings to gather supplementary information on how we arrived at specific budget estimates
- Program Budget Decisions (PBDs) issued by OSD are used to resolve most differences between Service BES* and OSD/OMB pricing. Remaining major issues are resolved by the DRB and SecDef
- Our Budget request, as approved by OSD and OMB, then becomes part of the President's Annual Budget Submission to Congress (usually in January). Congressional review and (hopefully) approval occurs during the months prior to the start of the FY 88 Budget year (1 Oct 87)
- In total, one cycle totals three years from the start of Air Force planning until budget execution begins

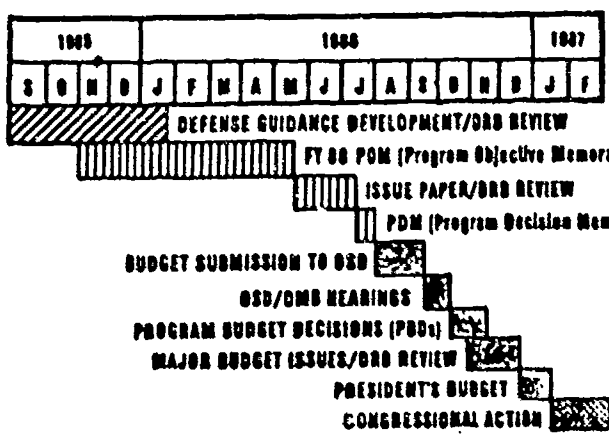


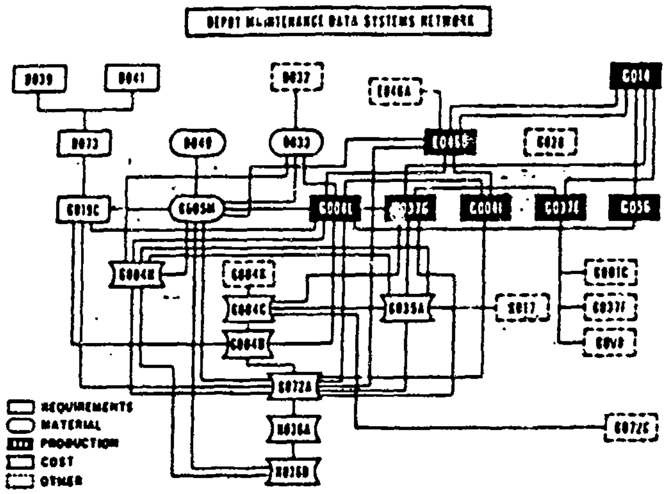
Figure IV-20. PPBS Sequence of Events

preference be given to small businesses. Fortunately, quality is now being given higher consideration, so the trend for contracts to automatically be awarded to the lowest bidder is finally being reversed (Canan, 1989). Nonetheless, even when AFLC manages to find a vendor that can provide high quality at a low price, the acquisition lead time for obtaining this part usually averages nearly three years.

Logistical Constraints

In TI's component repair and manufacturing divisions, parts availability was believed to be the most critical barrier to mission accomplishment. Prior to the hiring freeze, getting the right parts on time was the C-130 production division chief's top constraint. Parts problems exist, of course, because AFLC does not have an adequate parts projection system. Poor forecasting can be traced to deficiencies with the 30 different requirement, material, cost, production, and other interfacing systems in the depot maintenance data systems network (see Figure IV-21 for a diagram and definitions). These deficiencies stem from problems with system flexibility, system interdependency, data stratification, and information lag.

Most of these data systems were designed in the 1960s and are primarily second generation sequential, tape interface systems based on batch processing (DCS Maintenance, 1990). As a result, these systems are very



Selected Requirement and Material Systems:

D041 = Recoverable-Consumption Item Requirement System

G019C = MISTR Requirements, Scheduling, and Analysis System

D033 = Depot Supply Stock Control and Distribution System

G005M = Depot Maintenance Material Support System

Selected Production and Cost Systems:

G004L = Job Order Production Master System

G037E = Mission, Design, and Series (MDS)/Project Workload Planning

G035A = Depot Maintenance Budget and Management Cost System

G072A = Depot Maintenance Production Cost System

Selected Interfacing Systems:

D035 = Inventory Manager Stock Control and Distribution System

G001C = Maintenance Data Collection System

Figure IV-21. Depot Maintenance Data Systems Network

rigid and their information is often quite outdated. The G037E system for scheduling aircraft was not flexible enough to accommodate the C-130 production division's new 4-day, 10-hour shift schedule. Data from the D041 Recoverable Consumption Item Requirements System is generally poor and at least six months old. Nevertheless, D041 data comprises the primary source for computing AFLC buy and repair requirements.

The inability of depot maintenance data systems to properly overlay and interface is a continual source of frustration for planners and production controllers. Planners pointed out that the G005M Depot Maintenance Material Support System, which generates parts shortage lists, is frequently unable to communicate with the D041 system and the D033 Depot Supply Stock Control and Distribution System. In addition, information produced by these systems, particularly cost and performance measurement data, is sometimes too aggregated to be meaningful to managers. Finally, because the product directorate structure has created new directorates and new resource control centers (RCCs), many organizations have had trouble receiving the correct reports. Since the reorganization in October, 1990, the propeller branch production controller has not received any problem item stock number exception reports.

With the development and implementation of the Depot Maintenance Management Information System (DMMIS), AFLC

hopes to eliminate many of the deficiencies in the present data systems. DMMIS will replace 29 current maintenance systems and will employ real-time, on-line processing. It will incorporate MRP (Material Requirements Planning) II software and is supposed to provide AFLC with more effective scheduling and better financial management (DCS Maintenance, 1990). For DMMIS to be effective, its data inputs, especially those for bills of material (BOMs), routing files, and inventory records, must be highly accurate.

Planners and engineers in the TI directorate offered some insight into the problems that exist with the validity and accuracy of BOMs and work control documents (routings). Previously, AFLC regulations required that planners review and update work control documents (routings) once every two years. This requirement has now been deleted. This deletion, plus the recent reductions in the indirect workforce, has led to a greater number of inaccurate and outdated routings and BOMs in the system. In addition, the BOMs extracted from the G005M system only tell planners what has been replaced over the past eight quarters. They are not a complete inventory of all parts contained in a reparable end item. Furthermore, if an item of a particular stock number and part number is not repaired for eight quarters in a row, the BOM for this item automatically drops out of the system. The BOM for the C-130 aileron recently fell out of the system.

Another area of concern is shop flow day standards for exchangeables. Shop flow days are used by the D041 system to compute buy and repair requirements for exchangeable assets. Shop flow day standards are computed estimates representing the average number of calendar days required for an exchangeable asset to go through the depot repair process, measured from the date of receipt in maintenance to the date of serviceable turn-in (Air Force Audit Agency, 1989). A 1989 Air Force audit conducted at WR-ALC and the Oklahoma City (OC-ALC) and San Antonio (SA-ALC) ALCs revealed that shop flow day standards were incorrectly computed, were not adequately documented and reviewed, and were not updated in the G019C system. The auditors concluded that these conditions were caused by poor internal quality, administrative, and supervisory controls, by procedural weaknesses in AFLC directives, and by lack of compliance with these directives.

AFLC regulations for inventory management are also weak or nonexistent. For instance, there is no command guidance for ABC analysis or cycle counting. Also, AFLC regulations do not require organizations to take a sample of their inventory more than once a year. Furthermore, the size of these samples is generally based on the manpower available to conduct a physical inventory. Thus, samples of as few as ten items are not unusual. In preparation for DMMIS implementation, AFLC issued directives in 1988 for data cleanup of BOMs, routings, and inventory records. Since

that time, though, the command has taken no follow-up action whatsoever.

DMMIS project team members also observed that there are no requirements for personnel from outside an organization to audit physical inventories. Consequently, there is a strong tendency for units to report artificially high inventory accuracy rates. Under the former functional organization, quality was a separate division in the maintenance directorate and would have been the logical choice to audit inventory records. With the reorganization, quality personnel are no longer independent but work directly for branch and division chiefs in the various directorates to which they are assigned. Thus, a vital check and balance in the depot maintenance system has been lost.

C-141 Depot Maintenance
Warner Robins ALC, Georgia

Introduction

The C-141 Management Directorate is responsible for depot maintenance on the Air Force's C-141 aircraft and is one of six major product directorates at Warner Robins ALC (WR-ALC). Like the C-130 directorate, it must rely on other directorates at WR-ALC and at other ALCs to help support the accomplishment of depot maintenance on C-141s. Except for two repair actions, an aggregated flow chart for C-141 depot maintenance would closely resemble the chart shown in Figure IV-5 of the C-130 case. Obviously, such a chart would not

include a repair action for propellers. In addition, the cable/tubing and sheet metal repair action would be routed to both the PDM line and TI. This routing change reflects the fact that the C-141 directorate is currently developing an in-house capability for performing minor sheet metal repair, doing routine machining and welding, and manufacturing tubing and cables. Although the directorate will still route major work orders through TI's manufacturing division, the shops in its own Control Support Center (CSC) will soon be able to support all minor or routine sheet metal, cable/tubing, machining, and welding requirements from the C-141 aircraft depot repair lines. Because TI's general (conventional) machining and tooling and numerical control (NC) manufacturing branches are currently processing a major work order that supports C-141 center wing repairs, these two job shops were the area of focus in TI for this case.

The other directorate at WR-ALC which is critical to C-141 depot maintenance is the Avionics Product Directorate (LY). While the lack of an avionics LRU (line replaceable unit) rarely causes work stoppage on the C-141 PDM line, occasionally certain avionics LRUs must be cannibalized when they are not available from supply. Hence, in terms of avionics support, this case focuses on the avionics hardware production branch that repairs radar components used on various Air Force aircraft, including C-141s.

C-141 Directorate Overview

Organization and Workload

Depot maintenance for all Air Force C-141s is performed at one location, WR-ALC. Unscheduled depot maintenance repairs are sometimes referred to the prime contractor on the C-141, Lockheed Aeronautical Systems, in Marietta, Georgia. C-141 system program management responsibility also resides at WR-ALC. The requirements support and engineering/technical services support functions associated with system program management fall under the product support division, which is one of the four divisions comprising the C-141 directorate organization shown in Figure IV-22. Approximately 83 percent of the directorate's 1100 total personnel are employed in the production division, which is responsible for aircraft maintenance.

During FY 1991, 39 C-141s, each averaging 173 flow days, were scheduled for PDM at WR-ALC. For many years the PDM work package for the 270 C-141s in the fleet has been very stable and predictable. However, for the current fiscal year, the C-141 depot maintenance workload is much larger and more varied and complex than in the past. During FY 1992 three major types of work - PDM, center wing box replacement, and center wing repair of wing station 405 - are programmed for 96 aircraft. Twenty-four aircraft will undergo PDM, 24 aircraft will receive both PDM and center wing box replacement, and 48 C-141s will be scheduled for center wing repairs. Due to this tremendous increase in

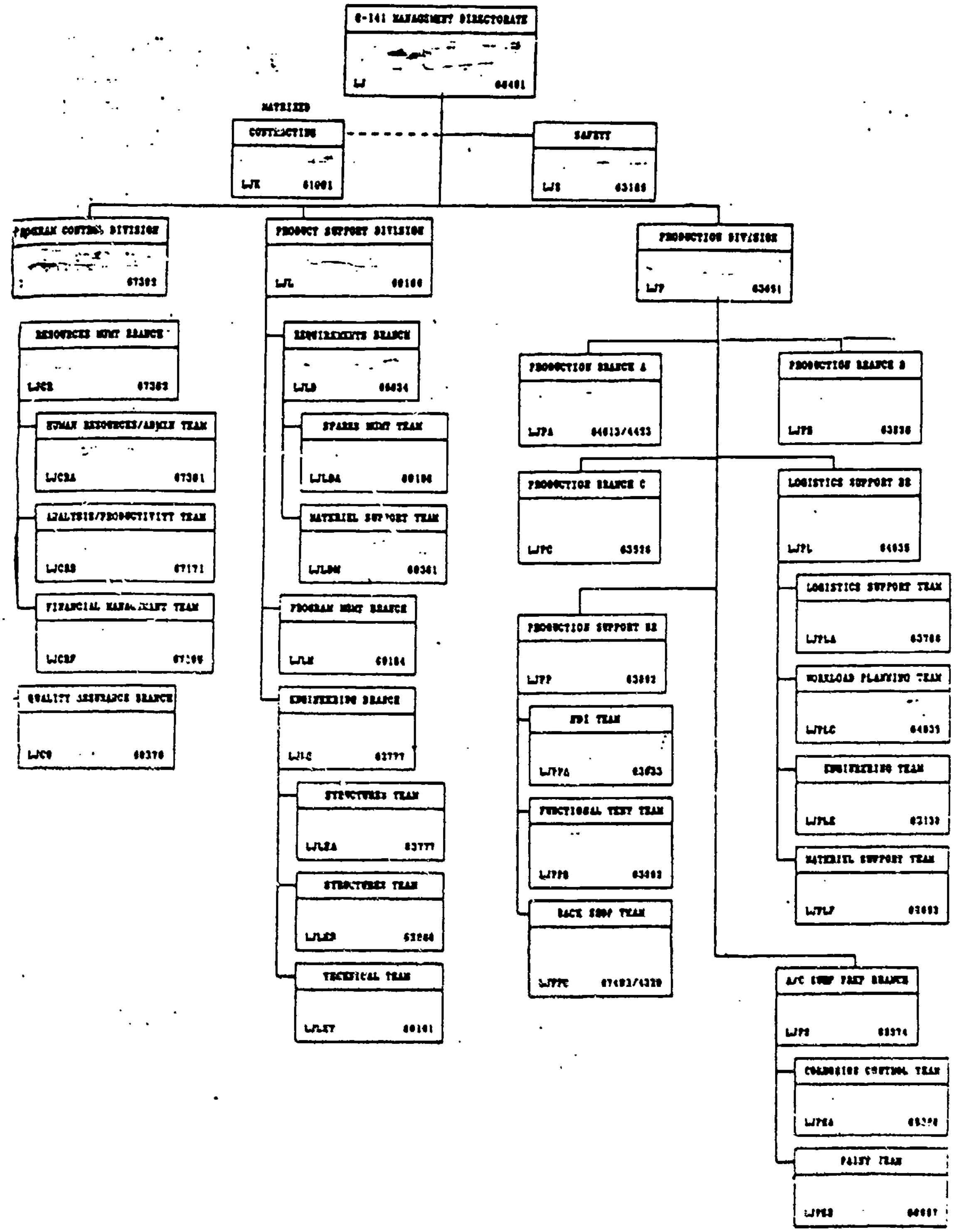


Figure IV-22. C-141 Directorate Organizational Structure

scheduled depot maintenance, in FY 1992 all unscheduled depot maintenance, which presently comprises 10 percent of the quarterly workload, will be done at Lockheed.

Goals and Objectives

Although the C-141 directorate performs depot maintenance on C-141s assigned to a Mississippi Air National Guard unit, a test wing at Wright Patterson AFB, and a NASA research center at Moffett Field, the majority of the C-141s sent to WR-ALC come from seven Military Airlift Command (MAC) units. These MAC wings are located at Andrews AFB, MD; Altus AFB, OK; Charleston AFB, SC; McChord AFB, WA; McGuire AFB, NJ; Norton AFB, CA; and Travis AFB, CA. To better serve these customers, the C-141 directorate has developed broad vision and mission statements and concrete goals and objectives. The directorate's vision is to provide the best weapon system depot maintenance, materiel support, and technical support within DOD, and by 1995, be the benchmark for similar organizations. Its mission is to provide cost effective and quality C-141 depot maintenance, materiel management, and technical support that maximizes combat airlift, readiness, and sustainability.

The four major goals of the C-141 directorate and the specific objectives related to each goal are provided in Figure IV-23. The second, third, and fourth goals are tied to the directorate's three discrete products outlined in the mission statement - depot maintenance, materiel support, and technical support. While the C-141 director considers the

C-141 MANAGEMENT DIRECTORATE
GOALS

GOAL 1: DEPLOY AN ACTIVE TQM PROGRAM BY THE END OF 1991

OBJECTIVES:
- ENSURE 100% TRAINING FOR ALL EMPLOYEES BY 31 SEP 91
- BASELINE QUALITY INDICATORS FOR EACH DIVISION, BRANCH AND TEAM.
- BASELINE COST OF POOR QUALITY INDICATORS FOR SUBSEQUENT REDUCTION
- IDENTIFY AND ESTABLISH IMPROVEMENT PROGRAMS FOR CRITICAL PROCESSES

GOAL 2: EXCEED CUSTOMER EXPECTATIONS FOR DEPOT MAINTENANCE SUPPORT

OBJECTIVES:
- PRODUCE PDM AIRCRAFT WITHIN $\pm$ 7 DAYS OF THE AMREP OUTPUT DATE
- HOLD DEPOT INVENTORY < 35; WR-ALC INVENTORY $\leq$ 24
- REDUCE AIRCRAFT FLOWDAYS TO < 130 DAYS
- DECREASE UNIT OUTPUT COSTS BY 5% FROM THE 1990 AVERAGE
- INDUCT AND WORK 44 AIRCRAFT REQUIRING TCTO 528

Figure IV-23. C-141 Goals and Objectives

C-141 MANAGEMENT DIRECTORATE GOALS

GOAL 3: EXCEED CUSTOMER EXPECTATIONS FOR MATERIEL SUPPORT

OBJECTIVES:

- SOURCE SELECT AND AWARD CONTRACTS ON SCHEDULE FOR THE FUEL QUANTITY INDICATING SYSTEM AND AWLS AUTOPILOT SYSTEM
- PREPARE/RELEASE MOD DOCUMENTS, DRAFT RFP'S, AND CONDUCT FORMAL REVIEWS FOR FY92 NEW STARTS WITHIN THREE MONTHS OF PMD RECEIPT
- DECREASE ADMINISTRATIVE PROCESSING TIME (EXCLUDING PERIODS SPECIFIED BY LAW) BY 25 PERCENT
- DECREASE MICAP HOURS BY 15 PERCENT FROM THE 1990 AVERAGE

GOAL 4: PROVIDE BEST IN CLASS TECHNICAL SERVICES TO SUPPORTED ORGANIZATIONS

OBJECTIVES:

- REDUCE PROCESSING TIME 25 PERCENT FOR 103'S, FIRST ARTICLES AND CVP'S
- CLOSE LOCAL 107 REQUESTS WITHIN 24 HOURS AND FIELD LEVEL 107'S WITHIN 72 HOURS OF RECEIPT
- REDUCE DO41 ERRORS BY 50% FROM 1990 AVERAGE

Figure IV-23. C-141 Goals and Objectives

four goals to be equally important, he emphasizes that three of the directorate's objectives are particularly critical for mission accomplishment. These objectives concern the establishment of improvement programs for critical processes, the reduction of aircraft flow days, and the reduction of MICAP hours. Because item management responsibility for a number of C-141 components resides at other ALCs, like OC-ALC, the C-141 directorate does not have nearly as much control over the third objective. To help reduce PDM flow days to 130, the production division is working to minimize the number of C-141s held in depot inventory at WR-ALC. This number now averages 18. To identify constraints in C-141 depot maintenance and achieve the first objective, the directorate is defining and baselining the various PDM processes. In addition, two of the directorate's long-term objectives are the establishment of a cost of quality audit and a benchmarking program. To begin laying the groundwork for these programs and learn how the competition fixes large aircraft, the C-141 director recently examined the maintenance operations at American Airlines and Delta Airlines.

Supporting Directorates

As noted in the introduction, for this case the research in the supporting directorates focuses on two branches in TI's manufacturing division and one branch in LY's production division. Although there are other branches and divisions in TI and LY that support C-141 depot

maintenance, none of these other areas was examined. Additionally, even though the avionics directorate at WR-ALC is AFLC's TRC for avionics, there are avionics facilities at other ALCs that repair C-141 avionics components.

Overview of TI's Manufacturing Division

The TI manufacturing division's 335 employees are divided among five branches - tooling and processing engineering, process support, sheet metal manufacturing, tooling and numerical control (NC) manufacturing, and general machining manufacturing. The latter two branches operate three shifts per day, five days a week, but the graveyard shift consists of just a skeleton crew. Prior to the reorganization, these two branches were one unit. Nearly all of their quarterly workload, as well as that of the entire division, is unscheduled maintenance. Approximately 50 percent of general machining work orders and 40 percent of NC jobs are in support of the C-141 aircraft depot maintenance lines.

Currently the most critical C-141 workload for these two branches involves the manufacture of four "gorilla" fittings and 15 associated parts to support C-141 center wing repairs. The general machine shop is making the two upper gorilla fittings, while the NC shop is manufacturing the two lower gorilla fittings. These fittings, which attach the inner and outer wing sections, are being replaced on all C-141s to correct and prevent problems with center wing cracks in the area of wing station 405. The new

gorilla fittings are made of an improved aluminum alloy material and have a sturdier design. The manufacture of a single lower gorilla fitting takes roughly 125 hours. A flow chart for this manufacturing process is displayed in Figure IV-24.

The general machining and NC shops are upgrading much of their equipment and technology. The NC branch recently installed Computervision, a system which is expected to save time and solve a number of long-standing problems. For instance, rather than having to rely on OO-ALC for post-processing, the branch will now have this capability in-house. Post-processing converts a computer program from high-level languages that humans understand to machine language the computer understands. In the past few years, the branch has also acquired a number of programmable three-axis and five-axis milling machines. The use of a three-axis milling machine reduced the manufacturing time for a receptacle for C-141 emergency escape doors from 40 hours to 20 hours. In addition, the recommendation by a machine shop TQM team to replace the fibroid lining on C-141 landing gear door bellcranks with a silver liner has improved the mean time between failure (MTBF) for the C-141 bellcrank from 30 days to five years. This team also redesigned the bellcrank to make it easier to install and universally adaptable to both the right and left landing gear doors. The cost and time savings that have resulted from this team's suggestions are an excellent example of how TQM can be used

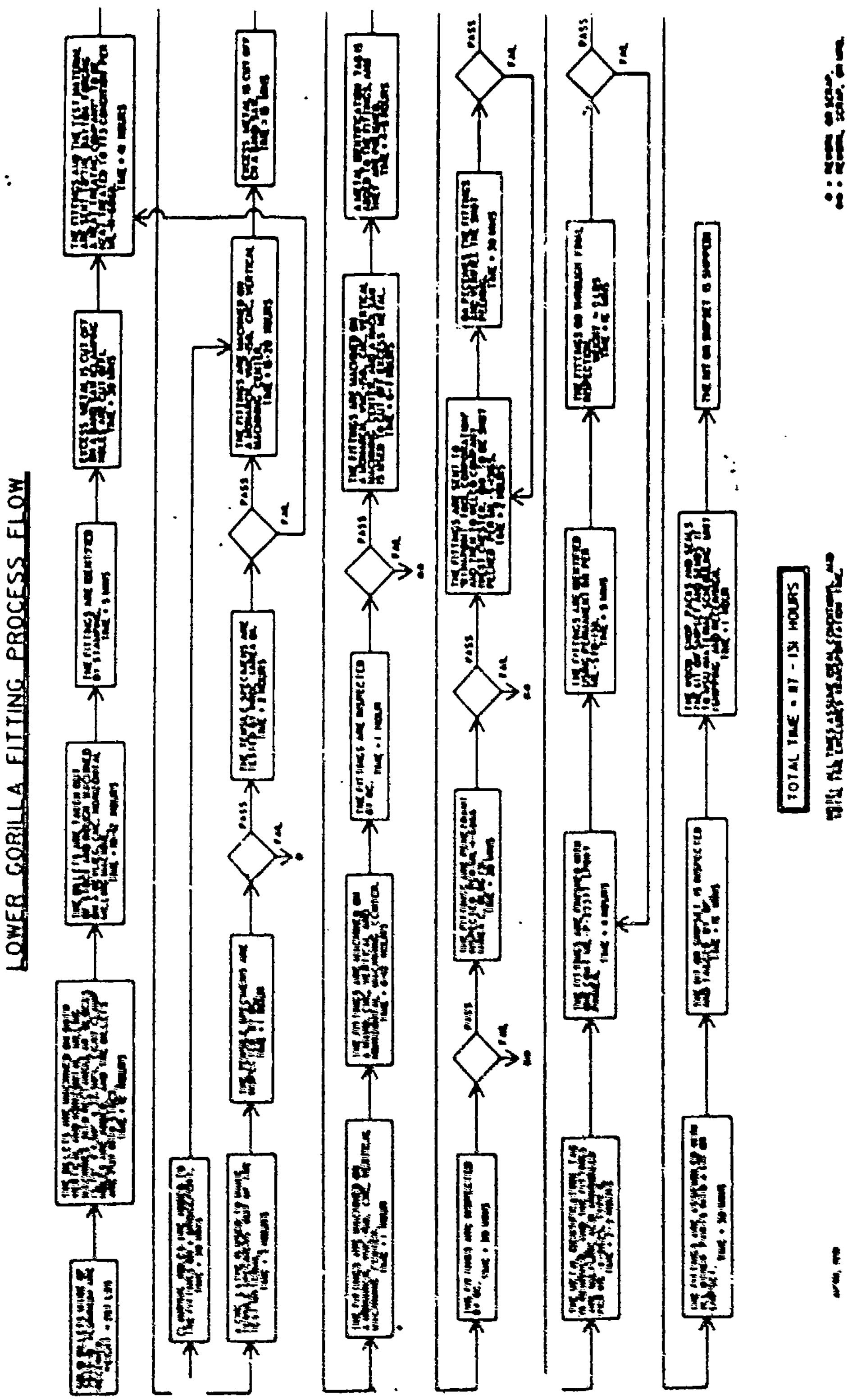


Figure IV-24. Lower Gorilla Fitting Process Flow Chart

to simultaneously improve depot maintenance, materiel support, and technical support, the three "products" outlined in the C-141 mission statement.

Avionics Directorate and Production Division Overview

Although various avionics components are repaired at all ALCs, WR-ALC's avionics directorate is considered to be the avionics TRC for the Air Force. LY repairs 80 percent of the Air Force's airborne electronics components, as well as a few avionics items for the Navy. The Navy items comprise five percent of the avionics production division's workload. The goal of the directorate is to give its customers what they want when they want it at the best price (value) and to provide quality products. LY's Air Force customers are the system program managers (SPMs) and operational units associated with the following aircraft: A-7, B-52, C-130, C-5, C-141, E-3, F-4, F-15, F-16, F-111, and H-1 helicopter.

Nearly 1300 of the 1700 employees in LY's four divisions - contracting, production, product support, and program control - are assigned to the production division. The production division consists of ten branches - five hardware production branches, three software production branches, a processing branch, and a resource management branch. The engineers reside in the processing branch; resource management contains the scheduling and materiel control functions. The division has almost 1000 direct laborers and typically operates one eight-hour shift during

the day, Monday through Friday. Additional shifts are employed on high-volume workloads or constraint-related operations, as required. Items scheduled through the MISTR program represent approximately 75 percent of the production division's hardware workload. The remaining 25 percent of this workload consists of unscheduled modifications/repairs, local manufacturing, software support tasks, and automatic test equipment maintenance. To handle fluctuations in the individual workloads of the 8000 different line items that the production division repairs, hardware personnel are routinely shifted among various workloads or work centers. In a typical quarter, these workers repair 39,000 units, resulting in sales of $80 to $100 million.

To make data collection easier and reduce the documentation burden on technicians, the production division is implementing Computer Integrated Repair (CIR). Bar-coded serial numbers on the LRUs (line replaceable units) and SRUs (shop replaceable units) in an avionics system provide the basis for the paperless data collection that is a key feature of the CIR process. With CIR, data inputs received from field activities, the depot, and the system manufacturer are transmitted to a historical database. Using information from this database, the depot is able to identify weak components to field units, so that they may be replaced prior to failure. Under current avionics maintenance practices, such components are only replaced after they have failed. (Weiss, 1990). Obviously, CIR is

extremely useful for focusing product improvement and increasing LRU/SRU reliability.

Unfortunately, because CIR requires highly integrated computer systems at all maintenance levels, it will only be used for the new weapon systems for which WR-ALC is assuming organic repair responsibility. However, the production division has developed a reliability tracking system which can be run on a Z-248 personal computer. The pilot effort for the implementation of this system is being conducted on the receiver transmitter (RT) for the APN-59 navigation radar system. The APN-59 system comprises at least 35 percent of the radar branch's workload and is a system employed on C-141 aircraft. A $372 thyratron tube on the APN-59 RT has traditionally had a high failure rate. Tracking depot repairs of APN-59 RTs by serial number, technicians recently discovered that the high failure rate of these tubes was linked to the bias value of a resistor on the tube's control grid. It was found that changing this $.16 resistor fixed 54 percent of bad tubes and could also be used to extend the life of bad tubes. Consequently, the replacement factor for thyratron tubes is expected to drop from 28 percent to 13 percent, resulting in a projected annual savings of more than $35,000.

C-141 Production Division Overview

Organization and Workload

The C-141 production division contains six branches - logistics support, aircraft surface prep, production

support, and three production branches. The logistics support branch works Monday through Friday, 7:30 a.m. to 4:15 p.m., and production support personnel provide coverage 21 hours per day, seven days a week. The remaining four branches operate 10 hours per day, seven days a week, either Friday through Monday or Monday through Thursday. Two of the three production branches perform all C-141 PDM. One of these branches has the additional responsibility of mating and demating wings on all C-141s. The third production branch reassembles C-141s that have completed PDM and also changes center wing box beams on all C-141s repaired at WR-ALC.

For safety reasons, over the next five years the center wing boxes will be replaced on 118 C-141s. The center wing box connects the wings to the fuselage. Unfortunately, this box was not designed to be removed from the aircraft. Hence, rather than being a simple remove and replace procedure, center wing box replacement is a complicated manufacturing task requiring 12,000 to 15,000 manhours per aircraft. Lockheed engineers are assisting WR-ALC in developing the procedures and tooling required for this project.

Center wing repair is expected to take 30 days of dock time per aircraft. This work involves inspecting an area in the middle of each wing where the inner and outer wings come together for cracks. To correct the cracks, improved gorilla fittings will be installed on the left and right

wings. On aircraft where installation of these four fittings fails to arrest the cracking, the rear beam segment at wing station 405 will be replaced.

To help the C-141 directorate handle the increased workload, AFLC has transferred some of WR-ALC's F-15 and C-130 workloads to SM-ALC and OO-ALC. The directorate has also been authorized to hire 350 additional production personnel. Although outside hires will be needed to fill a substantial number of these positions, some of these slots can be filled by the 42 vocational-technical graduates recently hired and by personnel transfers from other WR-ALC directorates. However, even with the additional maintenance personnel, a significant reduction in PDM flow days is essential for the production division to be able to repair 96 aircraft during the next fiscal year.

Flow for PDM and Center Wing Box Replacement

In the past there were no established job routings or sequences of events for accomplishing C-141 PDM. Therefore, to aid in developing and managing process flows, the C-141 directorate recently purchased a project management software package called Timeline. Timeline provides PERT (Program Evaluation and Review Technique) charts and Gantt charts and allows the loading of an unlimited number of resources per project. Because the center wing box replacement was a new workload involving just one area of the aircraft, it was used as the pilot project for Timeline implementation. Figure IV-25 illustrates the flow for center wing box

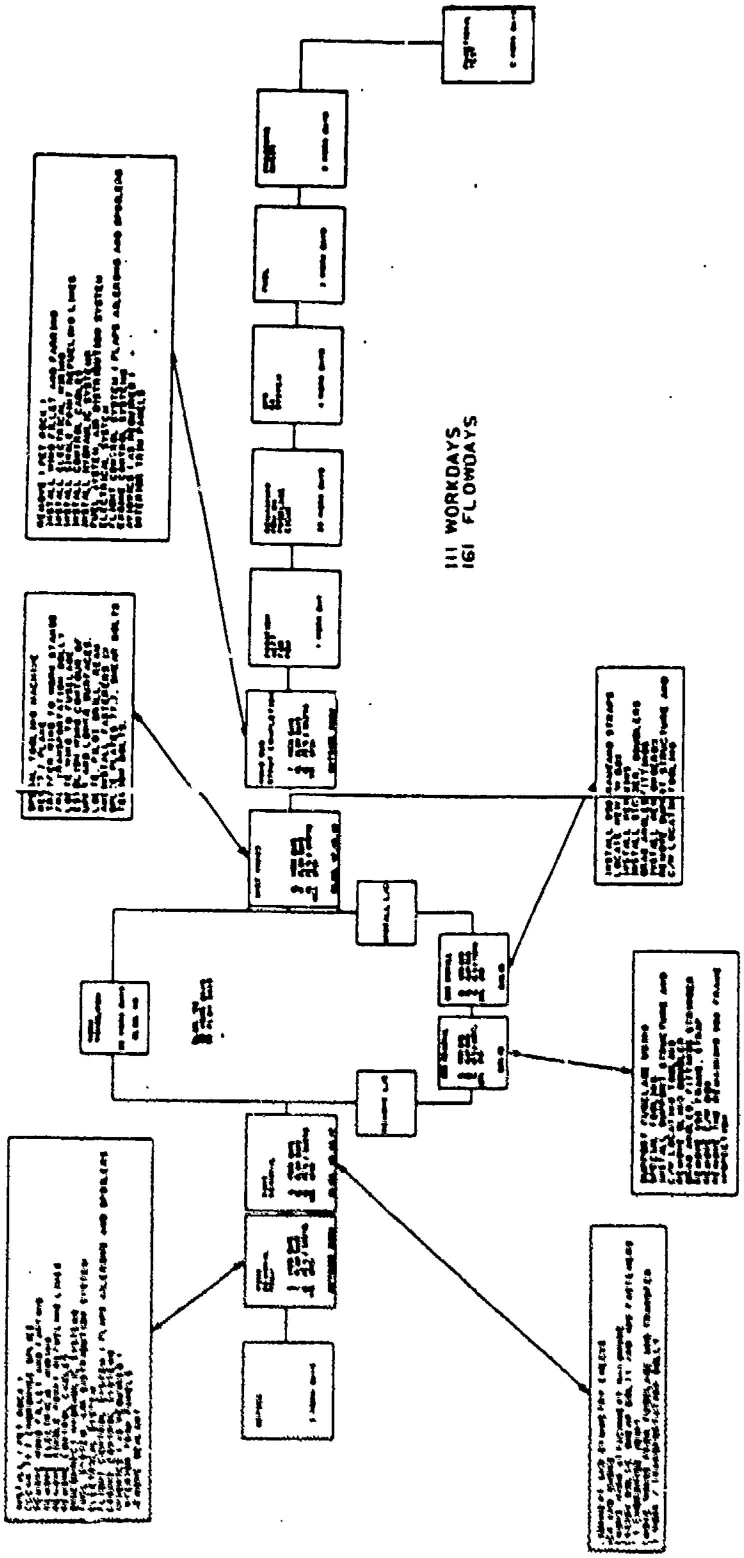


Figure IV-25. C-141 Center Wing Box Replacement Flow

replacement. C-141 engineers have expanded this chart to incorporate the entire C-141 PDM operation. They have already defined the detailed tasks involved in each major depot process and are now trying to link these processes together by dependent tasks. The final PDM model will include information on bills of material and special tooling requirements. It will also be able to perform resource leveling, track actual labor hours expended, and alert managers to missed suspense dates.

Although the basic flow for the C-141 PDM process outlined in Figure IV-26 does not include the level of detail illustrated in the C-130 PDM flow chart, many of the C-130 processes (except those related to propellers) are also applicable to C-141 depot maintenance. The C-141 PDM process is divided into three phases - prep, Speedline/PDM, and outprocessing - which correspond to the C-130's pre-dock, mod-dock, and post-dock phases. Speedline is the term for the maintenance line where the center wing repairs (designated in the chart by TCTO [technical time compliance order] 528) are accomplished. Proud MAC refers to MAC's initiative for repainting its C-130s, C-141s, and C-5s with a new gray paint that is more beneficial for controlling aircraft corrosion. If MAC decides to change its fleet to the new color, approximately 60 C-141s per year will be painted at WR-ALC.

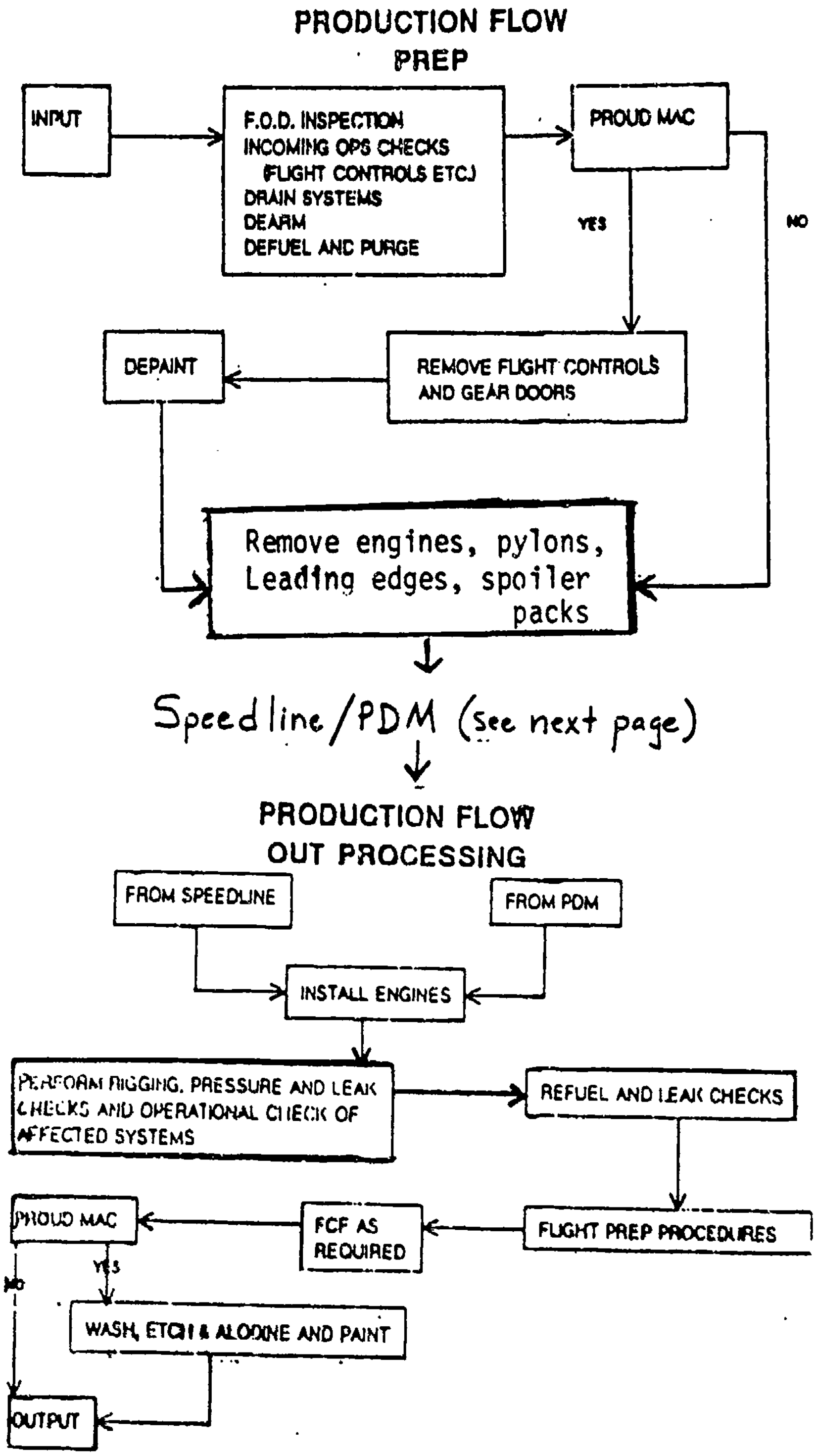


Figure IV-26. C-141 PDM Flow

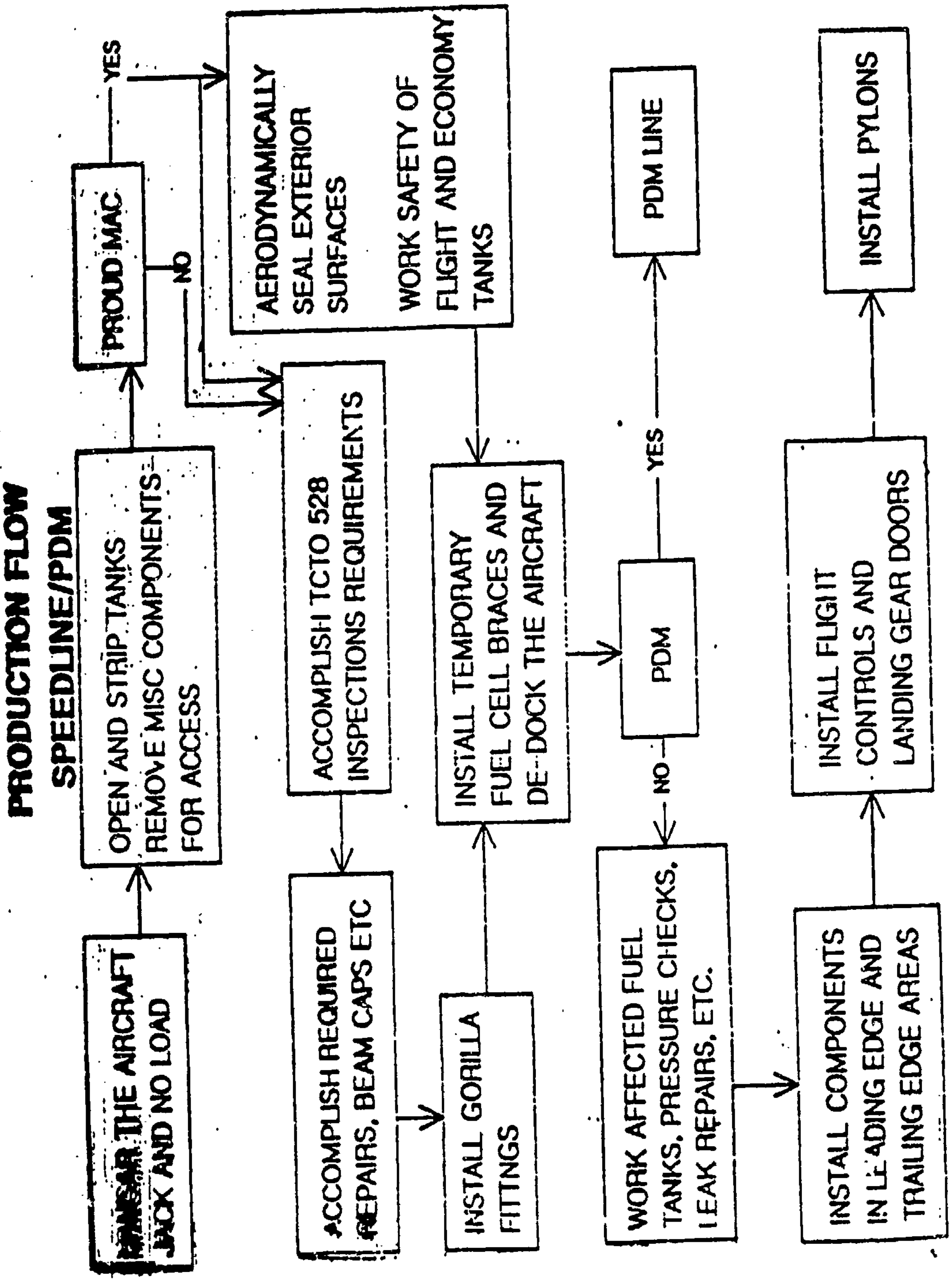


Figure IV-26. C-141 PDM Flow

Competitive Edges

Directorate and Division Rankings

Now that a brief overview of the C-141 depot maintenance workload has been provided, the importance that supervisors in the C-141, LY, and TI directorates place on certain competitive edges will be discussed. Selected directorate heads, division and branch chiefs, and first-line supervisors were asked to rank how critical the six competitive edges outlined in the C-141 case are for accomplishing depot maintenance in their organizations. The ranking scale and the two sets of rankings employed in this case are identical to those used in the C-130 case and in the other four cases in this study.

Figure IV-27 provides the three directorate-level rankings for the competitive edges. Considering the importance that the C-141 director places on reducing C-141 PDM flow days, it is not surprising that he ranked delivery as the most critical competitive edge on the basis of both unit objectives and performance criteria. Interestingly enough, on the basis of performance criteria, all three directorate heads ranked delivery as the most important competitive edge and cost as the second most important edge.

In contrast, as shown by Figure IV-28, the rankings of TI's manufacturing division chief and the chiefs of the C-141 and avionics production divisions exhibit much less similarity. The C-141 division rankings reflect the QCS (quality/cost/schedule) philosophy that is the basis for

C-141 Directorate (n=1)		
Rank Order	By Objectives	By Criteria
1	Delivery	Delivery
2	Quality	Cost
3	Cost	Quality
4	Lead Time	Lead Time
5	Flexibility	Flexibility
6	Innovation	Innovation

Avionics Directorate (n=1)		
Rank Order	By Objectives	By Criteria
1	Delivery	Delivery
2	Lead Time	Cost
3	Flexibility	Lead Time
4	Cost	Quality
5	Quality	Flexibility
6	Innovation	Innovation

TI Directorate (n=1)		
Rank Order	By Objectives	By Criteria
1	Quality	Quality
2	Cost	Cost
3	Delivery	Quality
4	Lead Time	Flexibility
5	Flexibility	Lead Time
6	Innovation	Innovation

Figure IV-27. Directorate Competitive Edge Rankings

C-141 Production Division (n=1)		
Rank Order	By Objectives	By Criteria
1	Quality	Quality
2	Delivery	Delivery
3	Lead Time	Cost
4	Cost	Lead Time
5	Flexibility	Innovation
6	Innovation	Flexibility

Avionics Production Division (n=1)		
Rank Order	By Objectives	By Criteria
1	Quality	Quality
2	Cost	Cost
3	Flexibility	Flexibility
4	Innovation	Innovation
5	Lead Time	Lead Time
6	Delivery	Delivery

TI Manufacturing Division (n=1)		
Rank Order	By Objectives	By Criteria
1	Innovation	Innovation
2	Quality	Quality
3	Delivery	Cost
4	Flexibility	Delivery
5	Lead Time	Flexibility
6	Cost	Lead Time

Figure IV-28. Division Competitive Edge Rankings

monitoring C-141 directorate performance. Because TI's manufacturing division chief believes that outdated technology is one of his division's major obstacles to improving its productivity and competitive capability, it is understandable that he ranked innovation as the most critical edge. The LY production division chief's ranking of delivery as the least critical edge does not mean that he considers delivery to be unimportant. He believes that the way to meet delivery schedules is to place a higher priority on other elements like quality and flexibility. In fact, this division chief lists quality, cost, and delivery as the top three indicators used to evaluate the performance of his division and his branches.

Branch and First-Level Supervisor Rankings

All six branch chiefs in the C-141 production division, four LY hardware branch chiefs, and the chiefs of TI's two machine shop branches evaluated the six competitive edges. The rankings pertaining to each directorate have been averaged and are reported in Figure IV-29. In the objectives category, the rankings of the two TI branch chiefs are nearly identical, with only lead time and delivery being reversed. Despite the fact that a larger number of C-141 production branch chiefs were surveyed, their rankings also exhibit a high degree of similarity. On the basis of unit objectives, these branch chiefs ranked quality as the first or second most critical competitive

C-141 Production Branches (n=6)				
Rank Order	By Objectives	Ranking	By Criteria	Ranking
1	Quality	1.33	Quality	2.00
2	Lead Time	3.00	Cost	2.17
3	Delivery	3.33	Delivery	2.67
4	Cost	3.50	Lead Time	3.67
5	Innovation	4.17	Innovation	4.83
6	Flexibility	5.67	Flexibility	5.67

Avionics Production Branches (n=4)				
Rank Order	By Objectives	Ranking	By Criteria	Ranking
1	Lead Time	2.25	Delivery	2.00
2	Delivery	2.50	Cost	2.75
3	Quality	2.75	Quality	3.00
4	Innovation	4.25	Lead Time	3.75
5	Cost	4.50	Innovation	5.25
6	Flexibility	4.75	Flexibility	5.75

TI Manufacturing Branches (n=2)				
Rank Order	By Objectives	Ranking	By Criteria	Ranking
1	Quality	1.00	Quality	1.50
2	Cost	2.00	Cost	1.50
3	Delivery	3.50	Delivery	3.00
4	Lead Time	3.50	Lead Time	4.50
5	Flexibility	5.00	Flexibility	4.50
6	Innovation	6.00	Innovation	6.00

Figure IV-29. Competitive Edge Rankings at Branch Level

edge and flexibility as the least or next to least important edge. On the other hand, the rankings of the avionics branch chiefs display considerable disparity. Their ranking of innovation as the fifth most critical edge in the indicators category represents one of the few instances where the rankings of these LY managers are in agreement.

Likewise, the competitive edge rankings of LY's first-line supervisors vary considerably. However, on the basis of both the objectives and indicators categories, they ranked flexibility as the fifth most critical competitive edge. The rankings of the TI and C-141 logistics branch first-line supervisors do not show much agreement either. Indeed, the only group of first-line supervisors whose rankings of the six competitive edges were fairly similar was the three first-line supervisors from the three C-141 production division's three production branches. The rankings of the first-line supervisors in each directorate have been averaged and are reported in Figure IV-30.

Performance Criteria

Directorate Performance Criteria

The C-141 directorate has developed internal and external monthly management reviews which look at the five management areas on which the C-141 directorate focuses - depot maintenance, materiel support, technical support, manpower and personnel, and financial management. Each of these reviews is divided into the categories of throughput (T), inventory (I), operating expense (OE), and net profit.

C-141 First-Line Production Supervisors (n=6)				
Rank Order	By Objectives	Ranking	By Criteria	Ranking
1	Delivery	2.00	Quality	2.00
2	Quality	2.17	Delivery	2.50
3	Cost	3.17	Cost	3.17
4	Lead Time	4.17	Lead Time	3.83
5	Innovation	4.50	Flexibility	4.33
6	Flexibility	5.00	Innovation	5.17

Avionics First-Line Production Supervisors (n=4)				
Rank Order	By Objectives	Ranking	By Criteria	Ranking
1	Lead Time	2.25	Cost	2.00
2	Delivery	2.50	Quality	2.50
3	Quality	2.75	Delivery	2.75
4	Innovation	4.25	Lead Time	4.00
5	Cost	4.50	Innovation	4.75
6	Flexibility	4.75	Flexibility	5.00

TI First-Line Manufacturing Supervisors (n=2)				
Rank Order	By Objectives	Ranking	By Criteria	Ranking
1	Delivery	1.50	Quality	1.50
2	Quality	2.00	Delivery	1.50
3	Innovation	3.50	Lead Time	4.00
4	Lead Time	3.50	Flexibility	4.50
5	Flexibility	4.50	Innovation	4.50
6	Cost	5.00	Cost	5.00

Figure IV-30. Competitive Edge Rankings by First-Line Supervisors

Each briefing includes different management indicators, with the internal review containing more detailed information on materiel support and financial management. The external review concentrates more on the depot maintenance and manpower/personnel areas and is the version presented to the center commander. Criteria from the two C-141 Management Directorate Monthly Management Reviews are listed in Figures IV-31 and IV-32.

The Avionics Monthly Management Review is divided into the functional areas of product support, contracting, and production. It clearly follows the center commander's prescribed "T-I-OE" format, especially in the contracting section. Overall, the topics presented (refer to Figure IV-33) are fairly evenly distributed among the throughput, inventory, and operating expense categories. In addition, the avionics director has proposed some new criteria to use for measuring the performance of the depot maintenance, contracting, and item management functions. A number of these criteria, which are summarized in Figure IV-34, are time-based and concentrate on assessing due date performance and lead time. Measuring MISTR production and due date performance on a biweekly basis is a major change from current practice. Such a criterion would certainly drive down inventories and improve depot responsiveness to customer demands.

Criteria from the TI Monthly Management Review were presented in the C-130 case. A more recent version of this

Throughput

1. C-141 Aircraft Production - Planned vs actual aircraft produced

2. C-141 Average Flow Days - Average number of flow days required to accomplish depot maintenance on C-141s

3. C-141 MC/NMC Rates - C-141 mission capable and not mission capable rates for maintenance, supply, and maintenance and supply

4. WRM Actions and Cann Actions - Number of withdrawals from WRM stock and number of cannibalizations per 1000 aircraft flying hours

5. AFLC Form 103 - Average number of days to comply with work stoppage and nonwork stoppage engineering change requests

6. First Articles - Average number of days for first article processing, broken down by time required for receipt, tech data review, testing, and evaluation

Inventory

7. Aircraft Inventory - Number of C-141s in depot maintenance status at all locations

8. Purchase Requests (PRs) in Process - Number of PRs and amendments currently being processed

Operating Expense

9. DMIF Manpower Status - Number of civilians authorized and assigned to the C-141 directorate

10. Monthly Civilian Regular Actual Hours - Percentage of direct and indirect manhours for civilian DMIF employees for current month

11. Direct Labor Overtime - Overtime in hours for each month of the current and previous fiscal years

12. Sick Leave - Sick leave as a percent of regular paid hours for direct labor; sick leave and annual leave percentages for each of the directorate's four divisions

Figure IV-31. External C-141 Monthly Management Review

13. Limited Duty and Compensation - Number of personnel currently performing limited duty or receiving compensation

Net Profit

14. Operating Cost vs Sales Revenue - Cumulative operating cost, sales revenue, and variance for each month of current fiscal year

15. Aircraft Completions (YTD) - Sales rate, actual rate, and variance by categories (labor, materials, other, general and administrative [G&A], overhead, and total) for aircraft completed in the current fiscal year

16. Categories of Cost per Hour - Direct labor, direct material, overhead, and G&A expenses for the most recent six months

Quality

17. Customer Reported Defects - Number of aircraft for which defects were reported during each of past six months; cumulative percentage of defective aircraft for the current fiscal year

Summary

18. C-141 Management Review Summary - Color-coded status ratings for the five management areas (depot maintenance, materiel support, technical support, manpower & personnel, and financial management) [Red = poor, yellow = fair, and blue = good]

*Note: Except where noted, the time period covered by all criteria is each month of the current fiscal year

Figure IV-31. External C-141 Monthly Management Review

<u>Throughput</u> (Time period is each month of current fiscal year)

1. MICAP Hours - MICAP hours for C-141 items by ALC

2. C-141 Top Ten MICAP Items - The ten items with the most accumulated MICAP hours in the current reporting month

3. Contract Processing Time - Average number of days required to process contracts

4. Contract Competition Rates - Percentage of contract dollars competed

5. Small Business Rates - Percentage of contracts awarded to small businesses

6. AFTO Form 22 - Average days to process tech data change requests

7. Total Assigned Strength of Civilian Personnel - Number of civilians assigned to direct, indirect, overhead, and O&M labor

8. Contract DMIF - Program execution for DMIF contract dollars

<u>Inventory</u> (Time period is the current month)

9. Government Furnished Material - Inventory on hand in dollars and in months for government furnished material

10. "G" Condition Assets - Quantity of units and total costs for assets awaiting parts

<u>Operating Expense</u> (Except as noted, time period is current month)

11. C-141 Safety Statistics - Number of first aid and lost time injuries for each month of the current fiscal year

12. TQM Training - Planned vs actual number of workers and managers trained in TQM

<u>Figure IV-32</u>. Internal C-141 Monthly Management Review

13. Budget Programs* - Funding status for BP11 modifications, BP12 support equipment, and BP initial spares budgets

14. DAF Funded Aircraft* - Funding status of direct Air Force funded C-141 aircraft

15. Command Funded Aircraft* - Funding for command funded C-141s

16. 3400 Sustaining Engineering* - Funding status of this program

17. Stock Fund* - Funding for the Reparable Stock Division (RSD) and System Stock Division (SSD) funds

18. 3400 Maintenance* - Funding status for software, interim contractor support, and contractor logistics support

19. Exchangeables - Dollar value of C-141 exchangeable workload by various categories (funded, requirement, negotiated, produced, and unfunded backlog) for each quarter of the current fiscal year

20. 3400 Operations - Authorized, target, and actual expenses for travel, overtime, and equipment/supplies

Net Profit

21. Operating Cost vs Earned Revenue - Operating cost vs earned revenue and resulting profit/loss for each month of the current fiscal year

22. Profit/Loss - Profit/loss statement for the directorate showing sales rates, actual rates, and variances by categories (labor, material, other, G&A, overhead, and total) for the current month

*Note: Funding status is given in terms of dollars authorized, dollars initiated, dollars obligated, and dollars committed

Figure IV-32. Internal C-141 Monthly Management Review

<u>Product Support</u>

1. LY Throughput Dollars - Sales for the current and past month

2. LY Throughput Units - Sales for the current and past month

3. RSD Inventory - Current level by categories (on order contract, applicable/inapplicable, and serviceable/ unserviceable)

4. O&M Operating Expenses - Operations and maintenance expenses for the current month

5. "G" Condition Assets - Dollar value of units awaiting parts

6. "G" Condition Assets - Number of units awaiting parts

7. MICAP Hours - MICAP hours, for each of the ten weapon systems that LY supports, for each month of the current and previous fiscal years

<u>Contracting</u> (Time period is each month of the current fiscal year)

8. PR $ on Hand - Dollar value of PRs on hand, excluding DMIF

9. PRs Received - Number of PRs received

10. PRs Received - Dollar value of PRs received

11. Undefined Actions - Number and percentage of delinquent contracts

12. Undefined Actions - Dollar value and percentage of delinquent contracts

13. Dollar Obligations - Amount of contract money obligated for the year-to-date and each month of the current fiscal year

14. PRs Completed - Number of PRs completed

15. $ Value of Products Received - Dollar value of these products

<u>Figure IV-33</u>. Avionics Directorate Monthly Management Review

16. $ Value of Products Delinquent - Dollar value of these products

17. Cost per Contract Action - Operating expenses per contract

18. % of Documents Reworked - Percentage for contracting paperwork

19. Line Item Delivery Performance - Total number of line items due, line items delinquent, and percentage of line items on time

20. LY Competition - Total obligated dollars, total competitive dollars, and competitive dollar percentage

21. Protests - Number of contract protests

22. Contract Processing Days - Average number of days required to process contracts

23. PR Processing Days - Average number of days required to process PRs

Production

24. LYP Throughput - Production in terms of negotiated dollars, produced dollars, negotiated output, and produced output for the current, past, and upcoming months

25. LYP Inventory - Inventory levels for current and past months

26. Shop Flow Day Reduction - Maintenance flow days and shop flow days, for each month of the current fiscal year, for 28 high volume/high revenue items (by NSN [national stock number])

27. Sick Leave - Percentage of budgeted, actual, and cumulative sick leave for each month of the current fiscal year

28. DMIF Operating Expenses - Expenses for G&A, salaries, overtime, supplies/equipment, TDY travel, and benefits for the current month

Figure IV-33. Avionics Directorate Monthly Management Review

Depot Maintenance

Biweekly MISTR Production and Due Date Performance

Shop Flow Days

Sales Price per Unit

Process Defects per Operation

Operation Hours (MTBR - Mean Time Between Removal)

Conception to Fleet Retrofit (average days)

Contracting

Due Date Delivery Percentage

Conception to Contract (flow days)

Purchase Price Comparison

Defects Reported (QDRs)

Operation Hours (MTBR)

Item Management

Fill Rates and Backorder Rates (MICAP hours)

Total System Flow Time

Total Cost per Unit

Decision Defects (customer complaints)

Conception to Fleet Retrofit

MTBR (hours)

Figure IV-34. Performance Criteria Proposed by the Avionics Director

briefing included the criteria previously outlined as well as additional information on sales, operating expenses, customer reported deficiencies, and customer support. Three of the four customer support slides concern TI's support of the C-141 center wing repair project. Figure IV-35 outlines these additional criteria and topics.

Division and Branch Performance Criteria

TI's manufacturing branch chiefs brief the manufacturing division chief weekly on the status of critical items, Quality Deficiency Reports (QDRs), and direct labor effectiveness. LY's production division branches update their division weekly on their progress toward meeting quarterly production requirements and on the status of the other five criteria included in the production portion of the avionics directorate's management review. Negotiated requirements versus produced output is the key indicator used to evaluate this division's performance. Quality, delivery, and cost (profit/loss) are the three primary areas used to evaluate branch performance in TI's manufacturing division and the avionics production division.

Each week the C-141 production chief conducts two status meetings, where aircraft job status and AMREP due dates are reviewed. In addition, the supply status of parts on order is briefed once a week. The C-141 product support division chief, who supervises the directorate's item managers, equipment specialists, and product engineers, also attends these meetings. As a result, the C-141 production

1. Direct Labor Effectiveness - By month for current fiscal year

2. Managed Overhead Expenses - Exact dollar value of actual outlays vs budgeted amounts for real property maintenance, tools and equipment, service contracts, ground support equipment, etc.

3. COD Funds - Cost of Operations Division funds allocated and obligated for overtime, travel, miscellaneous contracts, etc.

4. MIC Inventory - Dollar value of inventory in TI's six maintenance inventory centers

5. Material Expenses - Monthly direct and indirect materials costs for the current and previous fiscal years

6. Operating Expenses - Monthly managed overhead expenses for the current and previous fiscal years

7. G&A Expenses - Monthly for current and previous fiscal years

8. Sales - Monthly TI revenue for current & previous fiscal years

9. Customer Reported Deficiencies - Total reported, number requiring investigation, and number for information only for previous six months

<u>Customer Support</u>

10. Computer Integrated Manufacturing (CIM) - Status of TI proposal

11. Fastener Qualification - Status of qualification efforts for C-141 and F-15 fasteners

12. WS 405 Fastener Manufacturing - Production status for fasteners used in wing station number 405 of the C-141 aircraft

13. C-141 WS 405 - TI support of WS 405 repairs (NDI procedures and the manufacture of gorilla fittings)

<u>Figure IV-35</u>. Recent Additions to TI Monthly Management Review

division chief is now able to resolve parts availability and engineering problems more quickly than he could prior to the reorganization, when C-141 product support personnel belonged to a separate directorate.

System Constraints

Overview

The constraints present in the C-141 depot maintenance environment will be examined and classified under three categories: behavioral, managerial, and logistical. While manpower shortages and the need to change the mindset of the workforce were cited as obstacles to mission accomplishment, the remainder of the constraints in this case fall into the logistical category. Parts availability was noted as a major problem by branch chiefs in all three directorates. Physical constraints and market constraints, the other two categories of constraints considered in this study, are not applicable to C-141 depot maintenance. The workload for these three directorates, particularly the C-141 directorate, is definitely increasing. However, despite the greater workload, no supervisors regarded the physical layout of their facilities or a lack of sufficient space to be critical problems. The C-141 directorate was having trouble getting 800 amperage power installed in their primary maintenance hangar, but this difficulty stemmed from inflexible contracting policies rather than facility deficiencies. Although C-141 aircraft maintenance is conducted in six hangars spread over a large area, the

directorate is in the process of installing computer telephones in all these locations to improve communication and control.

Behavioral Constraints

The deputy director of the avionics directorate pointed out that the mindset of the civilian workforce, with its resistance to change, is the underlying cause of a number of problems in LY. Most of these problems relate to cross-training, quality defects reporting, acceptance of new performance criteria, and workload induction. To reduce the amount of overtime necessary to handle workload surges, LY wants to cross-train more production personnel. Because these technicians all possess the electronics job skill, avionics cross-training involves learning how to repair additional LRUs and SRUs, rather than developing proficiency in a new skill. Unfortunately, production branch chiefs often think that they do not have time to conduct cross-training, and workers are more comfortable repairing the items that they have fixed for years.

Similarly, technicians are reluctant to report internal quality defects because they believe that they will be punished. In addition, the depot maintenance data systems do not promote the collection of rework and scrap statistics. To motivate workers to report defects, the TI directorate is attempting to create new positive performance criteria. Also, as noted in the C-130 case, many workers and first-line supervisors still perceive efficiency,

instead of quality, to be the primary maintenance driver. To correct this misconception and foster acceptance of new performance criteria, LY is revising the job standards on which its performance appraisals are based. The elimination of direct labor efficiency as a critical performance element is one change being considered.

Finally, even though AFLC fiscal policy encourages quarterly workload induction, the tendency to induct work in large batches also stems from long-standing maintenance practices and personal concerns for job security. For years AFLC exchangeable repair has been a make-to-stock operation which has satisfied customer demands from large inventories. Directorate and division chiefs are now aware that high inventories increase operating expenses. However, branch and first-line supervisors still view a big backlog as a desirable "cushion" that ensures job security and also provides a convenient source of parts.

Managerial Constraints

The discussion in the C-130 case on the effects of DOD and AFLC policies regarding the hiring and promotions freeze, the DMIF budgeting process, stock funding of exchangeables, and pricing and acquisition procedures are applicable to the C-141 case and the other four cases in this study. The hiring freeze has been lifted for the C-141 directorate. Nevertheless, managers at all levels in this organization saw manpower shortfalls as being their most critical constraint. This viewpoint is quite

understandable, given the huge growth in C-141 workload over the next several years.

As for the reorganization, supervisors believ ..at the new organizational structure has streamlined t management process and made it easier to accomplish the mission. Some TI supervisors believed that the conventional and NC machine shops should have remained together in the same branch. Nonetheless, they were pleased with how the reorganization has better integrated the schedulers and planners with shop floor personnel. The C-141 director commented that he now has a much greater ability to effect change and can address problems in a day rather than taking two months to define them. Of course, he still is limited by the fact that item management and repair of many C-141 commodities is handled by other ALCs or by the Defense Logistics Agency (DLA). The C-141 CSC chief pointed out that DLA-managed parts are the ones that generally cause a majority of his parts availability problems.

Where items are managed and repaired by the same directorate or within the same ALC, fewer communication and control problems typically arise. For example, 70 percent of the items repaired by the avionics directorate are managed at WR-ALC, which substantially facilitates depot-level communication. Notwithstanding, adequate communication with customers, especially those at base units, is considered to be the most critical constraint in the avionics production division. Barriers to communication

exist because there is no linking mechanism between the depot and the field for tracking reliability and the performance of problem LRUs and SRUs. This lack of a feedback loop is further exacerbated by the long pipelines between the depots and the operational units and by the enormous quantities of items stuck in these pipelines.

The new policy for stock funding of exchangeables may make base units less inclined to ship LRUs to the depot for repair. However, LY's production division chief believes that there is a better way to keep inventory levels low and reduce depot operating expenses. Instead of charging operational units on the basis of each item repaired, he proposes to charge them on the basis of the number of hours an LRU operates before it fails. In other words, the depot would charge a firm fixed price per operating hour. He asserts that this policy would drive depot technicians to collect failure data, thus enhancing product improvement efforts. He also believes that the policy would eliminate more LRUs from critical item lists, thereby allowing item managers to focus on fewer items.

The other policy constraints noted by supervisors relate to training and short-term management. The C-141 logistics branch chief observed that AFLC does not enforce the use of tech. data and that the command's certification training program for its civilian production personnel is weak. For instance, too often individuals are signed off on tasks whether or not they are qualified to perform them. Of

course, with the recent manpower reductions, training deficiencies have become more obvious.

Short-term management refers to the military managers in AFLC and the resulting lack of continuity and policy consistency. Unfortunately, military directorate and division chiefs usually do not remain in a particular position for more than two or three years. Notwithstanding, the few lower-level supervisors who raised this issue do not realize that TQM and competition are not merely the current buzzwords but represent a new way of doing business. Even these individuals admitted that the military does a better job of training its enlisted personnel and giving them authority and responsibility.

Logistical Constraints

Logistical constraints, especially those related to planning, scheduling, and parts availability, were the type of constraint most frequently mentioned at division level and below. The avionics deputy director viewed lack of information for decision-making as his most important constraint. This problem results from inadequacies in the depot maintenance data systems network and the lack of a feedback mechanism between depot and base units. Without feedback from the field, LY has no visibility over base-level sales. Consequently, it is difficult to track retail sales (items issued by base supply units) and to predict what items might need repair in the future. DRIVE (Distribution and Repair in Variable Environments) is a

model which has been developed to prioritize depot repair and distribution actions to maximize aircraft availability. The model takes into account asset availability and customer demands and is being used by OO-ALC for F-16 avionics items. However, computerized serial number tracking of avionics items by base units at the intermediate repair level presently cannot be done for any Air Force aircraft other than the F-16. Hence, for most weapon systems, data inputs to DRIVE would be hard to obtain and of questionable accuracy. To better support customer demands, the avionics directorate is reinstituting a biweekly MISTR drive in concert with the AFLC guidelines for this program.

TI's deputy director illustrated how the inflexibility and outdated technology of the depot maintenance data network causes unnecessary work. The present data systems cannot recognize distinct types of aircraft for the workload type designator digit in the fifth column of a project order number. Therefore, pseudonumbers must be created so that project order numbers for all three aircraft product directorates at WR-ALC (C-141, C-130, and F-15) will be accepted when they are loaded into the computer.

In addition, the current data systems provide only historical information, offer no visibility over revenue, and do not capture profit and loss below the directorate level. To remedy these shortcomings, a WR-ALC financial management specialist who is knowledgeable in computer programming developed a program that forecasts cost and

revenue as of the current date. The program combines daily inputs from the G004L Job Order Production Master System and the G037A Maintenance Labor Distribution and Cost System. To provide real-time information, the program is being expanded to incorporate the G035A Depot Maintenance Budget and Management Cost System file and to input actual costs daily.

The deputy director for TI remarked that no constraints, only bottlenecks in operations and process flows, exist in his directorate. He talked about the need to eliminate the fat in some labor standards and to upgrade equipment so that TI can compete future workloads more effectively. For instance, a new system for automating temperature monitoring of the heat treating ovens should reduce much of the sheet metal rework formerly caused by oven temperature fluctuations. Excessive shop flow time and lengthy machine setup time were regarded as the two primary obstacles to mission accomplishment in TI's manufacturing division. To reduce shop flow days, the TI and C-141 directorates are working together to streamline the routing process for job routed items. TI is also considering implementing a computer integrated manufacturing system in the manufacturing division. Setup time is particularly a problem in the NC machine shop, where it may take weeks to program a machine. Computervision should reduce NC programming time by 50 percent. This system and a computer system borrowed from another TI division provide solid

modeling, electronic transfer of blueprints, and computerized extraction of special kinds of data.

The need to reduce flow times and improve planning and scheduling are some of the reasons why Timeline is being installed in the C-141 directorate. Timeline will also be used by the C-141 product support division to manage modification programs and perform file maintenance for the D041 item requirements system. In addition, the directorate has installed fax machines in the engineering and production areas to turnaround engineering change requests faster. The fax machines are especially useful for speeding the processing time for common requests, like those concerned with assessing the quality of fastener holes.

The C-141 director considers good planning to be the key to depot maintenance and lists the lack of coordination among planners, schedulers, and first-line supervisors as his second most critical constraint. Besides implementing Timeline, several other procedures have been initiated to reduce C-141 PDM flow days. Workload distribution among the production branches is much more equitable than in the past. Incoming aircraft are sent to whatever branch is most capable of handling the additional work at the time, rather than automatically being assigned to wherever they were originally programmed. Furthermore, the directorate has established a "nose-to-tail" agreement with its customers. The using commands do not input a C-141 to WR-ALC until the depot flies one back to them. Finally, to decrease the time

aircraft spend in functional test, mechanics are conducting more detailed inspections in the prep phase, particularly of the flight controls system. As the C-141 fleet has aged, flight control problems have increased. Therefore, to reduce the excessive number of functional check flights (FCFs) required due to these problems, the C-141 production support branch chief proposes raising the labor standards for rigging and operationally checking this system. Such an increase would allow mechanics to check the flight controls more thoroughly and would save time and money in the C-141 outprocessing phase.

The availability of the right part at the right time would also save time and money. Parts availability was the most frequently mentioned constraint, especially by branch chiefs and first-level supervisors. The C-141 production division chief and nearly every branch chief interviewed in each of the three directorates listed parts availability as one of their two most critical problems. The lack of control over parts removed from aircraft on the PDM line results in misplaced parts, double orders through supply, and unauthorized cannibalization. A primary purpose of the C-141 CSC is to track, order, inventory, and monitor the routing of aircraft parts. As parts are removed from aircraft, a bar code label is attached to them and they are routed through the CSC. The Timeline schedule is then used to determine the points in the depot repair process when particular parts are required. Besides controlling the

routing of aircraft parts, the CSC also performs the following production support tasks: issues and maintains bench stock, issues and maintains special tools, supplements kit shortages, provides parts/material pickup and delivery, and monitors cannibalizations. In summary, the CSC should provide planners and schedulers better visibility over all C-141s in depot maintenance at WR-ALC and help promote decisions that are in the best interest of the entire C-141 directorate.

F-4 Depot Maintenance

Ogden ALC, Utah

Ogden ALC Overview

The Ogden ALC (OO-ALC) at Hill AFB, Utah, focuses on being competitive and being committed to its customers. The center's vision statement and its four areas of focus (teamwork, customer satisfaction, continuous improvement, and being the supplier of choice) are shown in Figure IV-36. AFLC's recent reorganization was accomplished differently by each ALC. At OO-ALC, branches and sections were combined into units, and the lowest levels in the organization were designated as subunits. As shown by Figure IV-37, four major product directorates - Technology and Industrial Support (TI), ICBM (Missiles), Commodities, and Aircraft - were formed. OO-ALC's TI Directorate contains only a small number of backshops that directly support aircraft depot maintenance, and the ICBM Directorate is only concerned with missile maintenance. Hence, neither of these directorates

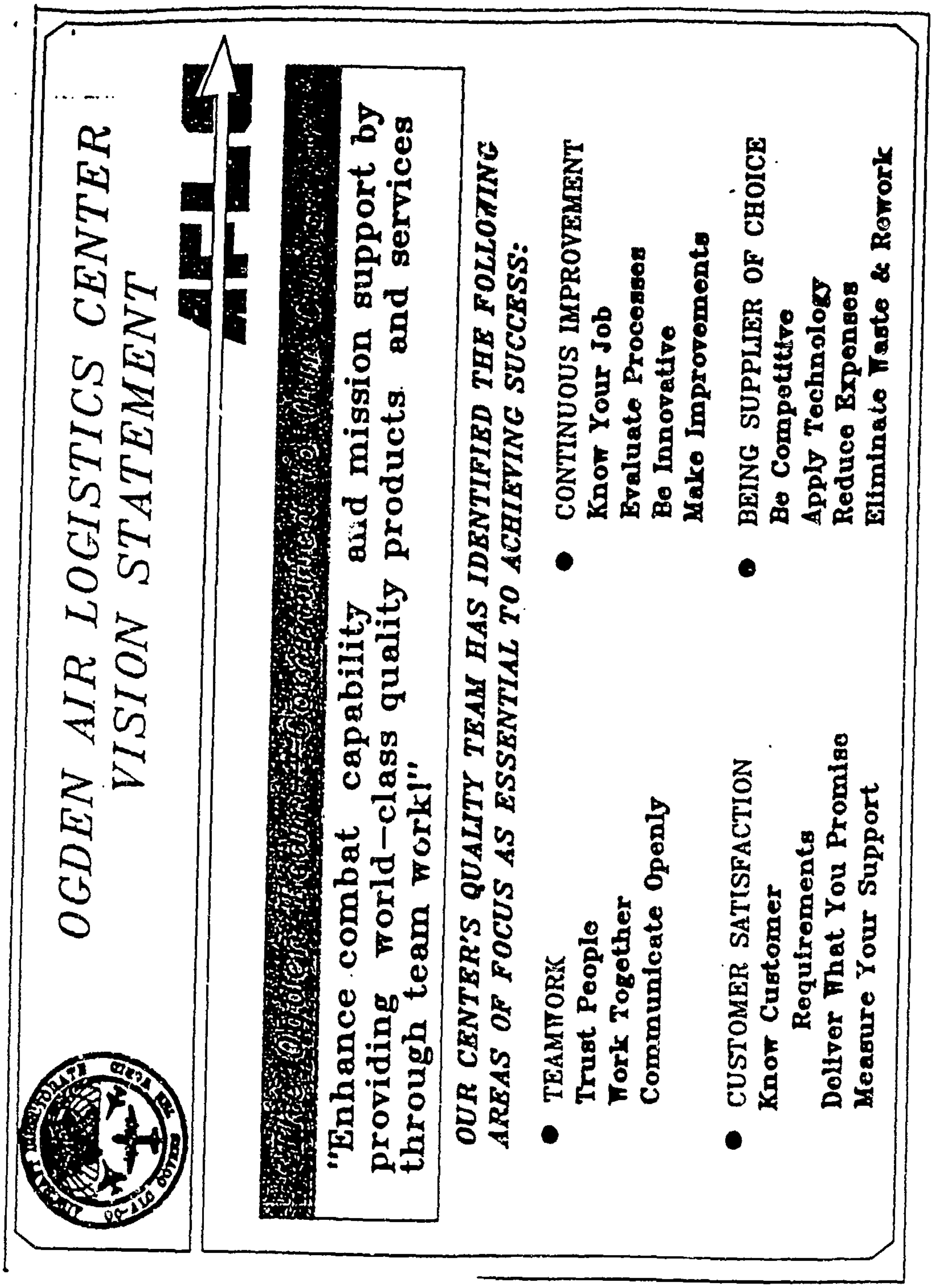


Figure IV-36. OO-ALC Vision Statement and Goals

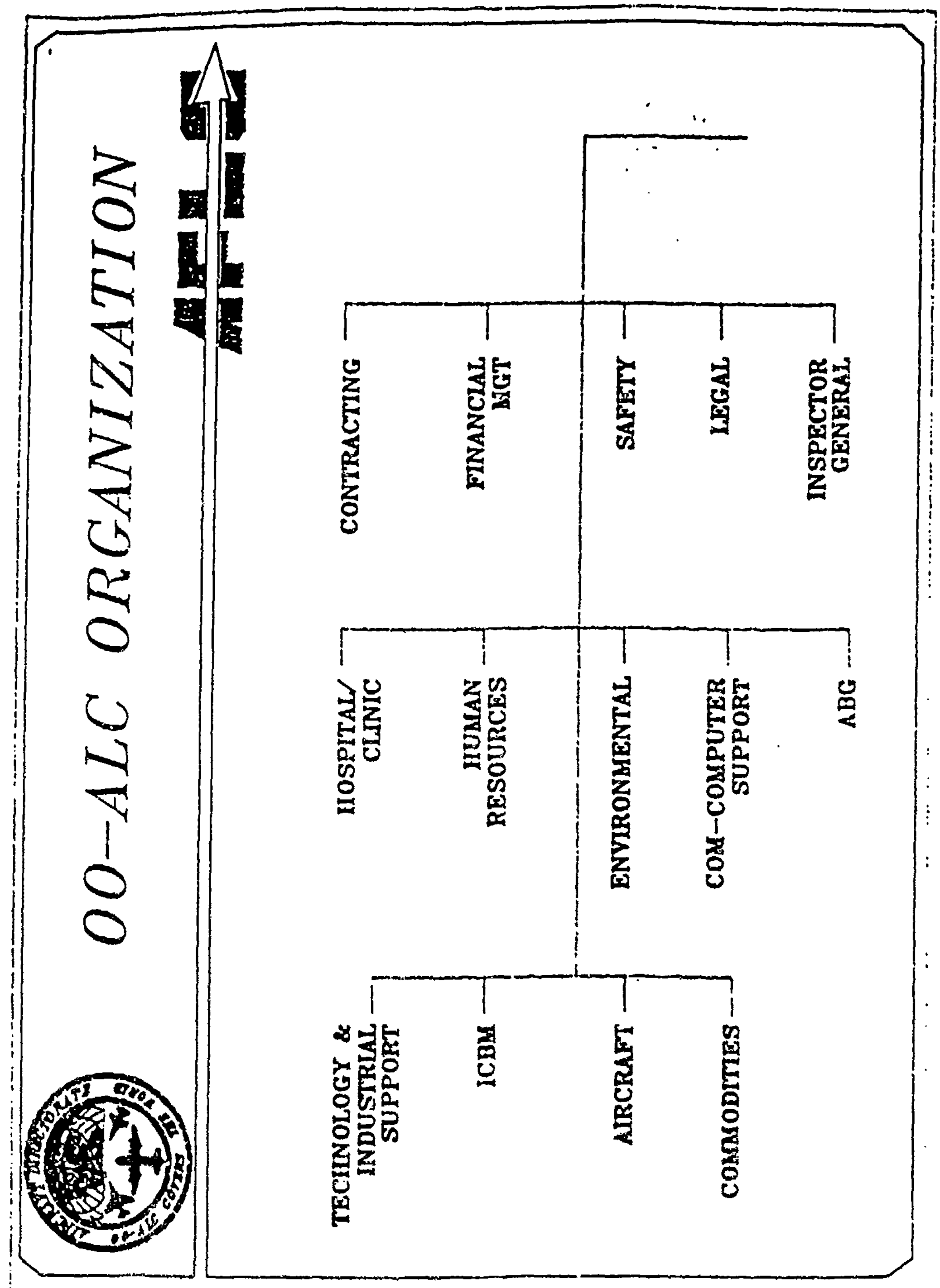


Figure IV-37. OO-ALC Organizational Chart

was examined in this study. The Commodities Directorate (LI) includes a large armament division and is responsible for repairing exchangeables, such as landing gear and photonics components. The Aircraft Directorate (LA) performs depot maintenance on F-4s, F-16s, and C-130s and has system program management responsibility for the F-4 and F-16 aircraft. Ir addition, many of the backshops that directly support aircraft depot maintenance, like the sheet metal and avionics repair shops, are part of LA. Therefore, the F-4 and F-16 cases will concentrate on OO-ALC's aircraft and commodities directorates.

Case Organization

Even though LA and LI support depot maintenance on both the F-4 and F-16 aircraft, this case will focus primarily on the commodities directorate and the F-4 production unit. Information on the aircraft directorate will be covered in the F-16 case. For the competitive edge rankings and the questions on rating the congruency of AFLC goals and depot objectives and of performance criteria and depot objectives, the LA and LI directorate-level responses, as well as those of LA's operations (LAO) and technical repair (LAR) divisions, were included in both cases. The F-4 case contains the LI landing gear division (LIL), LIL production unit and subunit (first-line supervisor), F-4 production unit and subunit, LAR structural repair unit and subunit, and LAR engines unit and subunit responses. The LI technical repair center division (LIT), F-16 unit and subunit, LIL engineering unit and

subunit, LAR support unit, and LAR avionics unit and subunit rankings are part of the F-16 case.

Overview of F-4 Depot Maintenance

Organization and Workload

DOD changes in force structure and recent Defense Management Review Decisions (DMRDs) to consolidate depot workloads are making long-term planning for the F-4 program extremely difficult. As F-4 aircraft are being phased out of the active Air Force inventory the F-4 workload at OO-ALC is dwindling from an average of 60 PDMs per year to the 20 PDMs scheduled for FY 1992. Of the 277 F-4s still remaining in the active fleet, half belong to Air National Guard units at Birmingham, AL; Boise, ID; Lincoln, NE; March AFB, CA; and Reno, NV. All but a handful of the rest of the F-4s are assigned to units at Spangdahlem AB, Germany; Bergstrom AFB, TX; and George AFB, CA. The actual number of F-4E, F-4G, and RF4-C models that will remain in the fleet is still uncertain, pending a final decision by the Air Staff. In addition, as part of a Joint Service Business Plan, the F-4 workload will soon be transferred to the Navy's Cherry Point depot. The transfer was to occur in FY 1992, but the Navy has yet to initiate the required actions for transfer.

PDM Flow and Drawdown Implications

The F-4 PDM package is well understood and has been relatively stable for 25 years. Figure IV-38 depicts the pre-dock, mod-dock, and post-dock phases of F-4 PDM. F-4

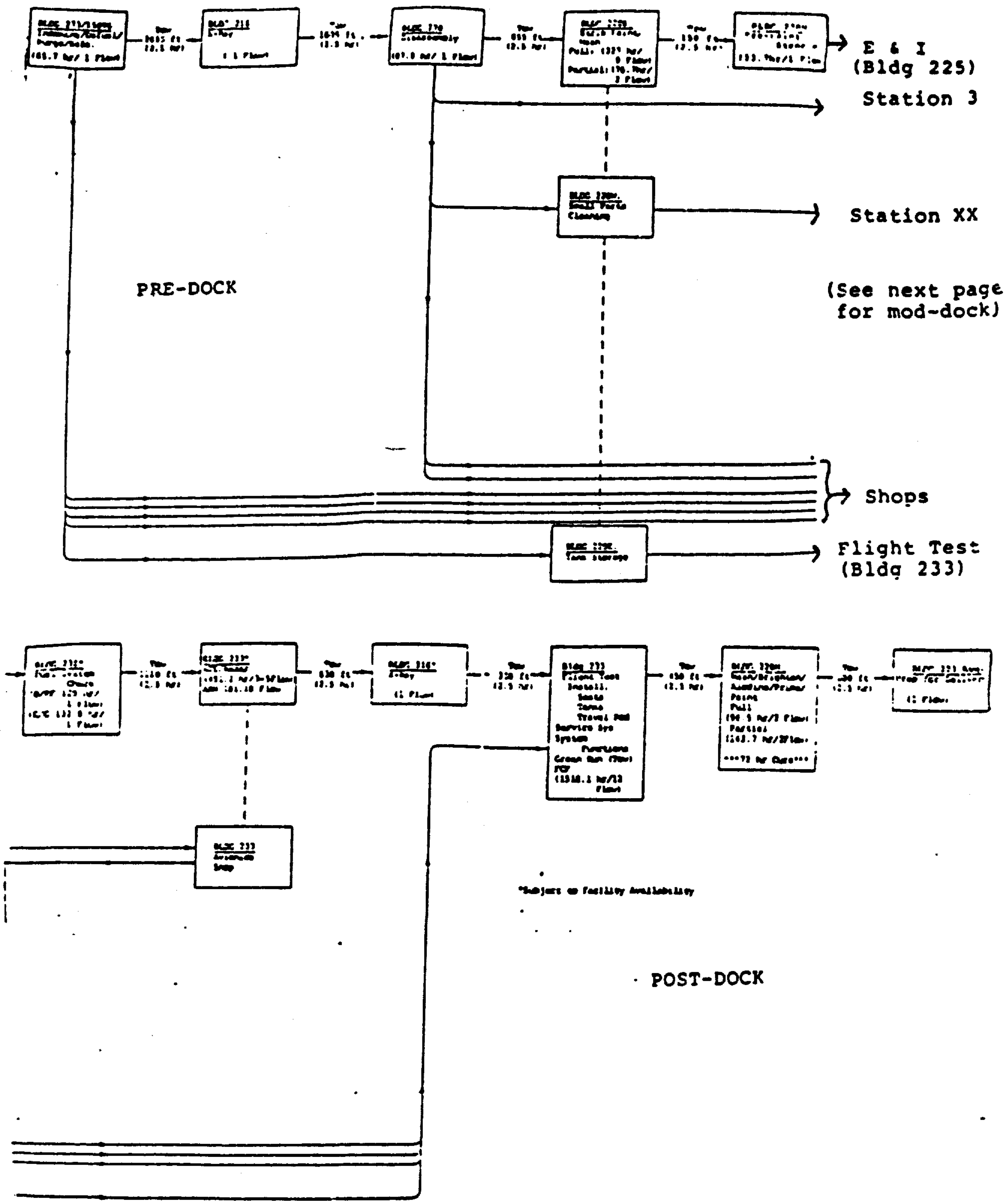


Figure IV-38. F-4 PDM Flow

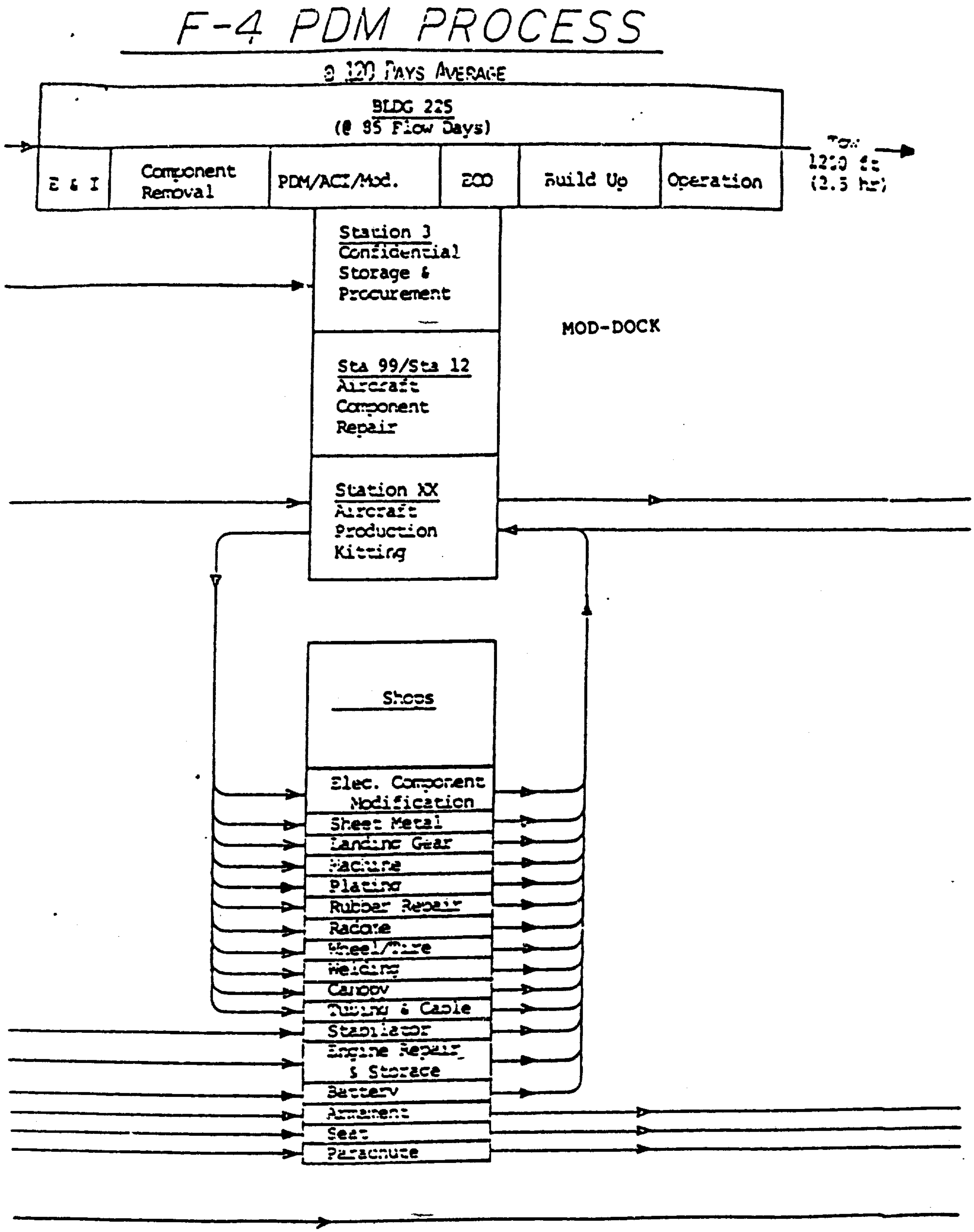


Figure IV-38. F-4 PDM Flow

PDM flow days average 150, with 120 days generally being spent in the mod-dock phase. Scheduled PDM maintenance represents more than 90 percent of the F-4 workload, so scheduling adjustments to accommodate drop-in aircraft are rare. Besides performing PDM on all F-4s assigned to the United States Air Force (USAF), LA's F-4 production unit is also responsible for PDM on all F-4s possessed by the Egyptian Air Force and on seven German F-4s stationed at George AFB, California.

Prior to the fleet drawdown, one of the biggest problems that the F-4 production unit had was getting F-4s scheduled into incoming and outgoing PDM processes like defueling, bead blasting, and painting. With only three paint booths at OO-ALC allocated to fighter aircraft, there is a tendency for F-16 aircraft, which comprise 60 percent of LA's workload, to be given higher priority. The F-4 drawdown has forced the aircraft directorate to realign its workforce and retrain a considerable number of F-4 mechanics on the F-16 and C-130 aircraft. In July, 1991, 600 people were assigned to the F-4 production unit's four subunits - aircraft repair, sheet metal, planning, and scheduling. Less than two months later, the number of personnel in these four subunits had been reduced to 450.

Commodities Directorate and Technical Repair Division Overview

As can be seen from the organizational chart in Figure IV-39, the commodities directorate consists of seven

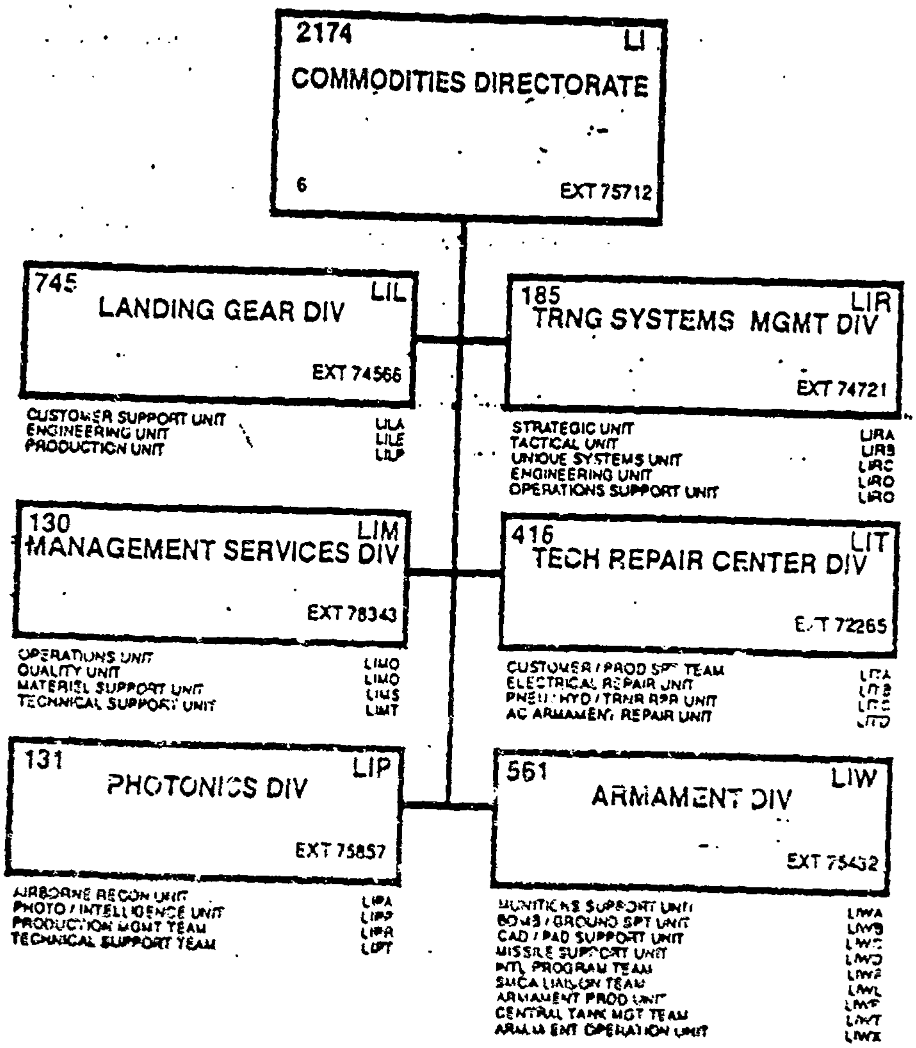


Figure IV-39. OO-ALC Commodities Directorate Organizational Chart

divisions - training systems management, management services, contracting, photonics, armament, landing gear, and the technical repair center. Only the landing gear division was examined in detail. The technical repair center division chief was interviewed, but the F-16 EPU (emergency power unit) subunit was the only repair shop visited in this division. This subunit is one of the few organizations in AFLC that has a statistical process control operation comparable to those in private industry. Just 40 percent of LI's 1900 employees are part of the direct labor DMIF workforce. Most LI personnel work a standard eight-hour day shift, Monday through Friday. Items scheduled through the MISTR program represent 70 percent of the workload for the directorate and for its landing gear and technical repair center divisions.

The LI mission is to enhance capability and mission support by providing world-class products and services through teamwork. The directorate accomplishes its mission by concentrating on the four areas of focus that OO-ALC considers essential to achieving success - teamwork, customer satisfaction, continuous improvement, and being the supplier of choice. The commodities directorate's overall objective is to deliver quality products to its customers in the quickest response time at values they can afford. To shorten the time between order entry and customer delivery, the directorate is considering the implementation of three systems - CIMS (computer integrated manufacturing), CALS

(computer-aided logistics system), and SPARES (spare parts production and reprocurement support system). The goal of CALS is the development of an Integrated Weapon System Data Base (IWSDB) that incorporates logistic support data and digital engineering product data into a shared, distributed data base which provides rapid availability of information to industry and DOD throughout a weapon system's lifetime. SPARES is intended to work in conjunction with CALS to automate engineering decisions related to manufacturing and allow spare parts to be made faster and cheaper.

Ninety percent of the technical repair center division's workload is managed by other ALCs, so the LIT division chief is particularly concerned with being the supplier choice. He believes that cost (profit/loss), quality, and delivery are the three main drivers for accomplishing the division's primary objective of giving the customer what they want when they want it. To better monitor operating expenses, the LIT chief has assigned a planner and a scheduler to perform this task on a full-time basis. These individuals are also conducting and/or arranging training for unit and subunit chiefs on 15 depot maintenance data systems critical for financial management. Formed in October, 1990, the technical repair center division was structured to give those in charge of its four units - electrical repair, pneudraulic/hydraulic trainer repair, aircraft armament repair, and customer/product support - more control over their resources. As a result,

LIT is one of the commodities directorate's most profitable divisions.

Overview of LI's Landing Gear Division

Mission, Organization, and Facilities

The landing gear division (LIL) at OO-ALC is responsible for the item management and depot maintenance of landing gear for all aircraft in the Air Force inventory. The division's mission statement and goals revolve around cost, quality, and schedule and are provided in Figure IV-40. LIL's customer support, engineering, and production units support three primary product lines - wheels, brakes, and struts. Two-thirds of the division's 600 total personnel are direct laborers in the production unit. LIL's landing gear overhaul facility, metal processing facility, new manufacturing facility, and thermal spray/investment casting shop cover nearly 500,000 square feet and contain equipment valued at over $33 million. These facilities employ some of the latest technology, including a digital numerical control/binary cutter language system, thermoplastics injection molding, and robotic plastics bead blasting. The NC and conventional machine shops perform machine manufacturing and repair for all OO-ALC units.

The production unit is organized into work teams by product families (wheels, brakes, struts) or by various processes, such as plating, grinding, and assembly. There are four production subunits - disassembly; landing gear, wheels, and brakes; metal processing; and manufacturing. In

LANDING GEAR DIVISION MISSION STATEMENT

The Landing Gear Division is committed to supporting the stated mission of the United States Air Force by providing serviceable landing gear components to support weapon systems in both peace time and war time environments.

Both the quality and timely delivery of our products and services are our primary objectives. To achieve these we are dedicated to building a highly trained, flexible work force to acquire and maintain landing gear support in a cost-effective manner and in compliance with environmental and safety standards. We will actively develop sources of supply outside the directorate to meet these same requirements.

In concert with our customers, we will develop processes and strategies to provide landing gear support to weapon systems for the least life-cycle cost.

GOALS

- BOTTOM LINE GOALS
  - COST
  - SCHEDULE
  - QUALITY

  THIS IS HOW OUR CUSTOMERS MEASURE US
- MANAGEMENT GOALS
  - THRUPUT
  - INVENTORY
  - OPERATING EXPENSE
- SUPPORTING GOALS
  - PEOPLE
  - CUSTOMER
  - COMPETITION
  - ENVIRONMENT

Figure IV-40. Landing Gear Division Mission Statement and Goals

the near future the schedulers and planners will be realigned under production and will be collocated with the production personnel. There are also plans to move some customer support unit product teams that presently work in a different area of OO-ALC to the production facilities. These teams are aligned by weapon systems and are comprised of logistics managers, production management specialists, product engineers, equipment specialists, and item managers. Eventually the production and customer support teams will be organized similarly according to either a process or a customer support orientation.

Workload and Competition Challenge

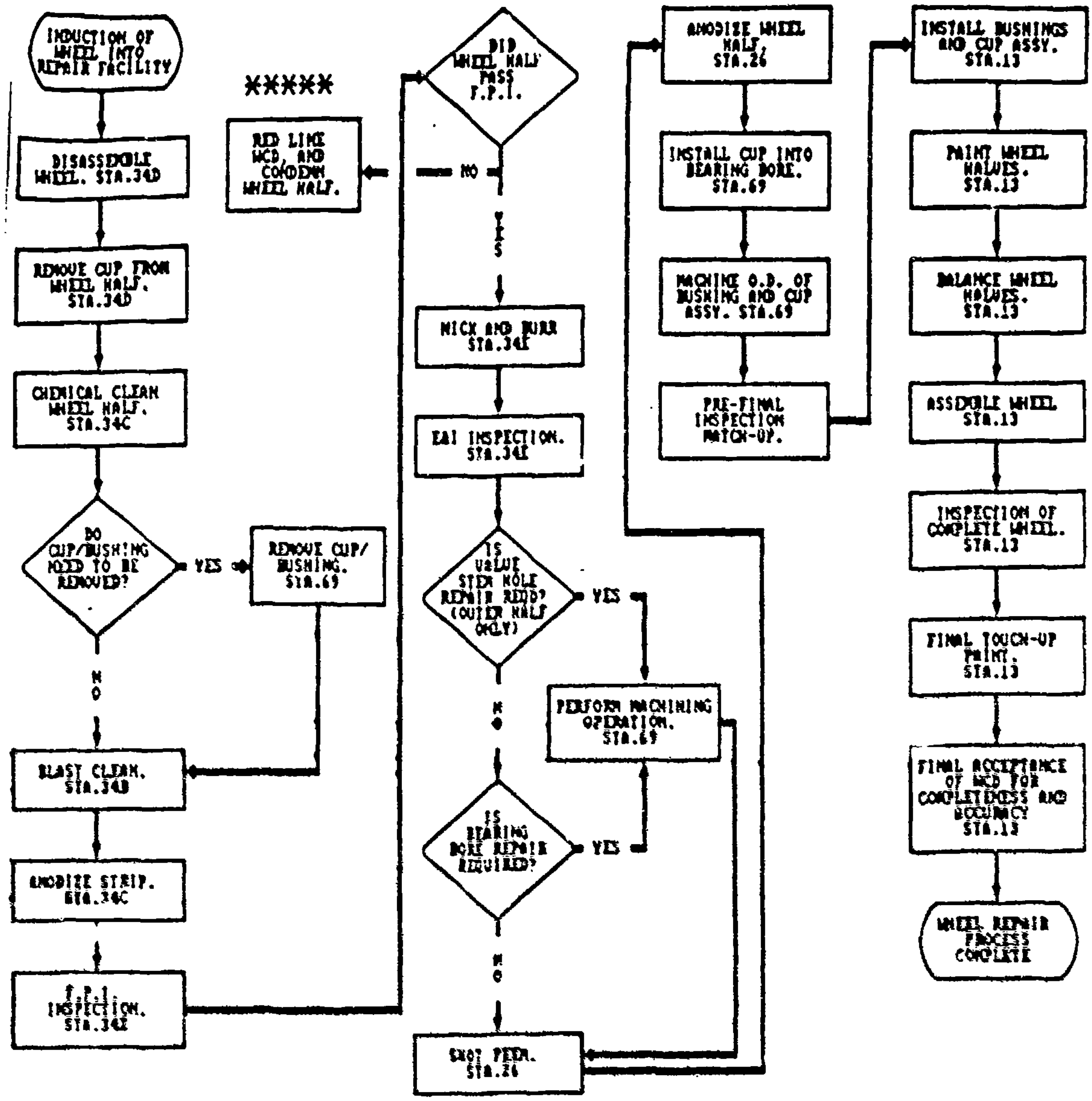
One of the purposes of the projected realignment is to help LIL become more competitive and more responsive to its customers. The depot maintenance workload competition driven by DMRD 908 poses the biggest challenge to the landing gear division and to the engineering unit in particular. For FY 1993, 70 percent of LIL's wheels workload will be competed against the private sector. Of the division's three product families, wheels experience the fewest parts problems and have the shortest average flow time (25 days). By contrast, brakes average 60 flow days, and strut repair is continually plagued by parts shortages, especially for bushings. Thus, wheels was selected as the first LIL workload to be competed and is currently the division's top workload priority. Sixty percent of this workload supports the C-5, C-141, KC-135, B-52, and F-16

aircraft. Failure to win this competitive bid will force LIL to suspend 93 direct laborers and possibly as many as 50 indirect labor personnel.

To help win this bid and meet the division goal of seven flow days for wheels, LIL's process engineers are identifying bottleneck operations in the wheel repair process and are analyzing wheel induction rates. Because the C-5 landing gear (wheels, brakes, and struts) workload will be used for the pilot implementation of DMMIS, the C-5 nose and main wheel repair processes are among the first ones that have been analyzed. The flow charts are provided in Figures IV-41 and IV-42. The engineers and planners are also updating work control documents (job routings) and labor standards to ensure the accuracy of labor and material costs. Finally, to assure LIL competitiveness for the long term, the engineering unit chief is endeavoring to break the sole source proprietary data rule on wheels and brakes. By owning the engineering data, LIL will no longer have to rely on three private contractors for engineering changes. Funding has already been received for redesigning C-141 wheels and brakes.

The manufacturing subunit, LIL's prototype area for competition, recently won a portion of a bid for the manufacture of LEFRA (leading edge flap rotary actuator) brackets for the F-16 LEFRA modification. Within 50 days of contract award, LIL delivered to LA the first of eight types of brackets at a price lower than that quoted by private

C-5 NOSE WHEEL FLOW CHART



**** NOTE: WHEN WHEEL HALF IS CONDEMNED, THE GOOD HALF MUST BE PUT ASIDE UNTIL ANOTHER MATCHING HALF IS LOCATED.

Figure IV-41. C-5 Nose Wheel Flow Chart

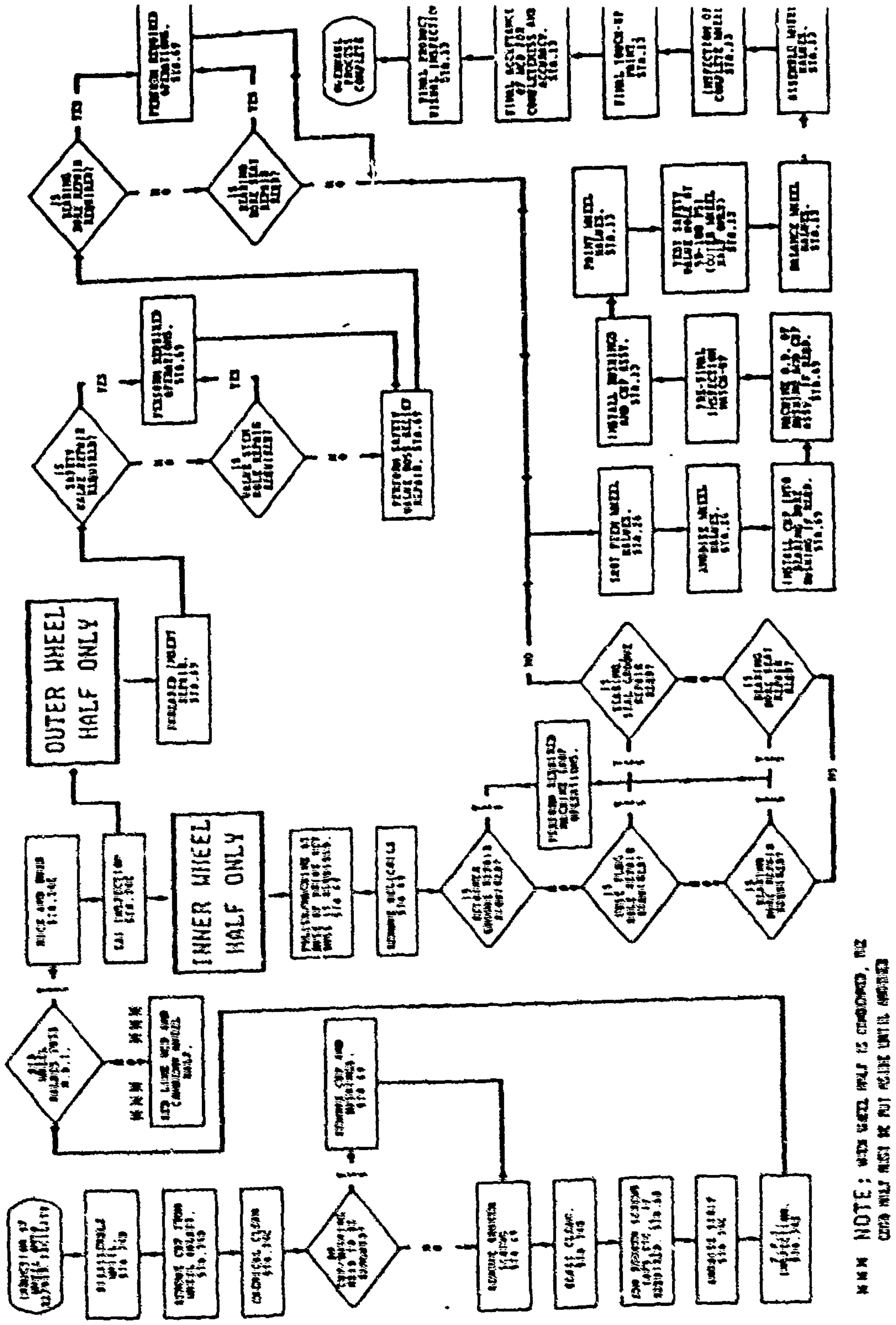


Figure IV-42. C-5 Main Wheel Flow Chart

industry. By buffering the bottleneck operation (investment casting) and by using shipping buffers and predetermined lot sizes, LIL achieved a 99.9 percent due date delivery performance rate over a five-month period. By contrast, the private contractors have yet to deliver the first bracket to OO-ALC's aircraft directorate.

Competitive Edges

Directorate and Division Rankings

At directorate level there was considerable agreement between the aircraft and commodities directorates on the ranking of competitive edges by objectives. Both directors believed the three most important edges to be quality, flexibility, and innovation, in that order. They both saw these three elements as being essential to producing their products in a timely manner at the least cost. However, in the criteria category, the aircraft director ranked cost and delivery as the second and third most critical edges. Considering the command emphasis on fiscal management and customer expectations on meeting AMREP due dates, this ranking is quite logical. The commodities directorate also ranked quality, flexibility, and innovation as the most important edges in the criteria category. This ranking indicates that there is probably little conflict between how LI division performance is evaluated and what these divisions must do to accomplish their objectives.

In the objectives category, little similarity exists among the rankings of the three division chiefs. Overall,

these managers rank cost and quality among the three most critical competitive edges and consider innovation to be relatively unimportant. While the aircraft operations division (LAO) chief deems flexibility to be fairly important, this same element is rated as the least critical edge by the aircraft technical repair (LAR) and LI landing gear division chiefs. Due to the continual changes in DOD force structure and AFLC aircraft workload distribution, for the aircraft operations division, flexibility is a necessary condition, rather than merely a competitive edge. The LIL and LAO rankings in the criteria category are nearly identical, with only the rank order of innovation and lead time being reversed. By criteria, all three division chiefs rank cost and quality among the top three edges. However, the LAR division chief ranks lead time as the second most important edge. He reasons that timely customer delivery cannot be achieved unless component parts are received when they are needed. The directorate and division rankings are illustrated in Figures IV-43 and IV-44.

Unit and Subunit Rankings

Compared to directorate and division rankings, the competitive edge rankings of unit and subunit chiefs (see Figure IV-45) display a much stronger agreement in both the objectives and criteria categories. Considerable similarity between the categories themselves also exists for both groups. This similarity, though, probably stems from the difficulty that lower-level supervisors sometimes have in

Aircraft Directorate (n=1)		
Rank Order	By Objectives	By Criteria
1	Quality	Quality
2	Flexibility	Cost
3	Innovation	Delivery
4	Cost	Flexibility
5	Lead Time	Innovation
6	Delivery	Lead Time

Commodities Directorate (n=1)		
Rank Order	By Objectives	By Criteria
1	Quality	Quality
2	Flexibility	Flexibility
3	Innovation	Innovation
4	Lead Time	Lead Time
5	Delivery	Delivery
6	Cost	Cost

Figure IV-43. Directorate Competitive Edge Rankings

Aircraft Operations Division (n=1)		
Rank Order	By Objectives	By Criteria
1	Cost	Cost
2	Quality	Quality
3	Flexibility	Delivery
4	Delivery	Innovation
5	Innovation	Lead Time
6	Lead Time	Flexibility

Aircraft Technical Repair Division (n=1)		
Rank Order	By Objectives	By Criteria
1	Quality	Quality
2	Lead Time	Lead Time
3	Cost	Cost
4	Delivery	Delivery
5	Innovation	Innovation
6	Flexibility	Flexibility

Commodities Landing Gear Division (n=1)		
Rank Order	By Objectives	By Criteria
1	Delivery	Cost
2	Cost	Quality
3	Quality	Delivery
4	Lead Time	Lead Time
5	Innovation	Innovation
6	Flexibility	Flexibility

Figure IV-44. Division Competitive Edge Rankings

Aircraft and Commodities Unit Chiefs (n=4)				
Rank Order	By Objectives	Ranking	By Criteria	Ranking
1	Quality	1.25	Cost	1.75
2	Delivery	2.25	Quality	2.00
3	Cost	3.25	Delivery	2.25
4	Flexibility	4.25	Flexibility	4.75
5	Innovation	5.00	Innovation	5.25
6	Lead Time	5.75	Lead Time	5.75

Aircraft and Commodities Subunit Chiefs (n=7)				
Rank Order	By Objectives	Ranking	By Criteria	Ranking
1	Quality	1.27	Quality	1.29
2	Delivery	1.86	Delivery	2.14
3	Cost	3.43	Cost	2.71
4	Lead Time	4.14	Lead Time	4.14
5	Flexibility	5.14	Flexibility	5.43
6	Innovation	5.14	Innovation	5.29

Figure IV-45. Competitive Edge Rankings by Unit Chiefs and First-Line Supervisors (Subunit Chiefs)

distinguishing between the objectives and criteria categories. In both of these categories, the rankings of each set of supervisors fall into two distinct groups. Lead time, flexibility, and innovation are regarded as the least important competitive edges, while quality, delivery, and cost are considered to be the most critical edges. The quality-delivery-cost rank order applies to all rankings except those of unit chiefs in the criteria category. Given the emphasis that division chiefs place on profit/loss management, it is not surprising that these supervisors rank cost as the most critical edge. As a rule, OO-ALC subunit chiefs are expected to deliver quality products on time, while unit chiefs are held responsible for producing these items at the least cost.

Performance Criteria

F-4 Production Unit Criteria

The criteria shown in Figure IV-46 are presented as part of the aircraft operation division's semimonthly management review to the aircraft directorate. Because this case focuses on LI, the other management indicators employed by the LAO and LAR divisions will be discussed in the F-16 case. The F-4 criteria focus on training, production, and internal and external quality ("J" items and customer reported defects). Profit and loss information is presented to the aircraft director in a separate weekly meeting.

1. F-4 Production Flow - Scheduled and actual aircraft production for the past three months; negotiated flow vs. actual flow by tail number; number of days delivered early or late

2. F-4 Flight Test - Defect and flight rates for F-4 flight test

3. "J" Items - Trends in flight test defects; number of aircraft delivered and number of "J" items reported for the latest month

4. F-4 Customer Reported Defects - Defect rate and number of major and critical defects reported during each of the previous 12 months

5. F-4 Training - Courses taught, number of people trained, and number awaiting training for the latest month

6. LAO Sick Leave by MDS (%) - Percentage of sick leave taken by F-4 subunits during the latest month and for the year to date

7. F-4 Overtime - Direct and indirect overtime for each F-4 subunit for the latest month and the year to date

8. F-4 JON (Job Order Number) Analysis - A breakdown of the direct product standard hours (DPSHs), direct material and labor expenses, overhead, and G & A expenses for every open job order number (each aircraft)

Figure IV-46. F-4 Production Unit Criteria

<u>LI Directorate Criteria</u>

The LI director and deputy director meet with their division chiefs once a month to discuss the progress they are making toward the center's four areas of focus and their own division goals. Instead of outlining specific numerical objectives, the directorate provides a range of effectivity for profit/loss and other performance indicators. At these meetings the division chiefs also point out areas in which they need directorate assistance. These monthly management reviews consist of roundtable discussions, rather than detailed slide presentations. LI's directors believe that such formal reviews encourage managers to gloss over certain information. Directorate profit and loss status is reviewed once every three weeks in a separate meeting attended by all LI division chiefs and by representatives from the SC (communications-computer) and FM (financial management) directorates. In addition, the division chiefs update the directorate monthly on the status of TQM/QP4 programs and initiatives.

LI wants to tie their management indicators to their quality program. Although LI updates the center commander monthly, the directorate is not required to give a formal slide presentation. However, because AFLC is now requiring each ALC to submit inputs for the DDPMS criteria, the indicators shown in Figure IV-47 were recently developed to comply with this new command requirement. The numbers in the brackets indicate the center area of focus to which the

1. MISTR Exchangeable Repair Workload - Actual production vs. negotiated output requirements by hours, by units, and by dollars for each quarter of the current fiscal year [1, 2]

2. DMIF Output per Paid Manday (OPMD) - OPMD for each month of the current fiscal year [3]

3. DMIF Profit and Loss - Monthly and cumulative profit/loss for each month of the current fiscal year [2, 4]

4. Execution of Program Authority in Central Procurement (CP) Funds - Amount of CP funds authorized, initiated, and obligated during the current and two previous fiscal years [2]

5. Execution of Program Authority in O&M Funds - Amount of O&M funds authorized, initiated, and obligated during the current fiscal year for travel, supplies/equipment, and DPEM [2]

6. Manpower - Number of O&M and DMIF personnel authorized and assigned for each month of the current fiscal year [none]

7. Directorate Critical Item Status - Number of critical items within category (i.e., problem, potential, critical, and total) for each of the past four quarters [1, 3]

8. Directorate TQM/QP4 Environment - Effectiveness of LI in attaining the goals set forth in the LI vision statement, as determined from employee surveys. The TQM benchmarking and President's award criteria equation is used to assign a level from 1 to 5 in four areas - leadership, training, structure, and process improvement. The LI goal is to attain a level of five by FY 1995. [1, 2, 3, 4]

Figure IV-47. OO-ALC LI Management Indicators

indicator corresponds. The number 1 denotes the customer satisfaction focus area, 2 stands for teamwork, 3 represents continuous improvement, and 4 designates supplier of choice.

Landing Gear Division Criteria

To monitor division production and progress toward division goals, LIL holds a weekly review of critical production requirements and a weekly product line meeting. The purpose of the production review is to identify and resolve production problems. This review examines the hours and the units negotiated, required, and produced for three LIL organizations (division, production unit, and manufacturing subunit) and the three product lines (wheels, brakes, and struts), as of the current date. A breakdown of the production unit's MISTR workload for the three product lines by hours and by percentages is also given. The remaining slides provide a negotiation/completion history in units and in hours for the division for each of the past ten quarters.

The status of each LIL product family is reviewed once every three weeks. Although the product line examines production problems and negotiated versus produced MISTR workload, it primarily focuses on material supportability. It looks at the specific end items which are experiencing parts problems and presents an analysis of the various material support problems. Thus, both production and customer support personnel compile information for and

attend product line reviews. In addition, to the management indicators that are already part of the production and product line reviews, the following performance criteria are being considered for implementation in the division: total productivity (sales divided by LIL production head count), profit/loss, defect rate trend, WIP trend, customer service level, equipment availability, skill mix/cross training, safety, absenteeism, and suggestion rates. Figure IV-48 contains the information presented in a recent wheels product review. The same topics are covered in the brakes and struts briefings.

System Constraints

Overview

Because the focus of this case is on the commodities directorate, the constraints discussed in this section are primarily those pointed out by LI managers and supervisors. Though the repair versus buy issue discussed under managerial constraints is being worked by an aircraft directorate PAT, it has greater impact on F-4 parts repair and therefore is included in this case. Nearly all of LI's constraints fall in the logistical category, and the majority of them are related to parts and material supportability. A few behavioral and managerial constraints also exist. Before looking at the constraints noted by LI management, the constraints affecting F-4 aircraft depot maintenance will be examined briefly.

1. MISTR Work Load Review (Units) - Units negotiated, required, and produced for the current or most recent quarter

2. MISTR Work Load Review (Hours) - Hours negotiated, required, and produced for the current or most recent quarter

3. Production Problems - Number negotiated, on work order, and completed for specific end items (by nomenclature and NSN [F-4 nose wheel, F-15 A/B main wheel, etc.])

4. Parts Problems - Number negotiated, on work order, and completed for specific end items (by NSN and nomenclature for which parts problems exist)

5. Material Supportability (Overall Type) - Total number of material support problems in each of seven categories (bill of material, delinquent contract, funding shortfall, item manager action, production ordered late, not following tech data, unforecasted requirements)

6. Material Supportability By Problems - Rank ordering of types of material support problems (according to the seven categories in the previous item [#5]) by aircraft weapon system

7. Material Supportability By Weapon System - Material support problems grouped by weapon system

8. Material Supportability By Prime Source - Total material support problems by source of supply

Figure IV-48. OO-ALC Landing Gear Division Product Line Review

The primary type of constraint facing the F-4 production unit is a market constraint resulting from the DOD force structure changes and depot workload transfers. As the F-4 production unit chief observed, his biggest problem is keeping work in the depot. Due to the tremendous uncertainty regarding the exact numbers and models of F-4s that are to remain in the active Air Force fleet, it is difficult for the aircraft directorate to do any long-term planning, particularly in terms of PDM schedules and manpower allocations. The ambiguity surrounding the timing of the planned transfer of F-4 PDM to the Navy's Cherry Point depot further exacerbates this situation. The drawdown of the F-4 fleet also means that the aircraft directorate must retrain a substantial number of F-4 mechanics so that they may be transferred to the F-16 and C-130 workloads.

Behavioral Constraints

As was true at WR-ALC, efficiency is still ingrained in sections of the workforce at OO-ALC, especially in the landing gear production unit. Direct labor effectiveness is one of the three primary indicators that the unit uses to evaluate subunit performance. Not surprisingly, all subunit chiefs listed effectiveness as one of the three principal criteria used to evaluate their performance. Only the manufacturing subunit chief recognized some of the fallacies associated with using direct labor effectiveness as a primary indicator of performance. Fortunately, the

manufacturing subunit is the section being used as the LIL prototype for competition.

At LI's directorate and division levels, effectiveness is merely one of the indicators used and does not appear to be given nearly as much emphasis as profit/loss status and MISTR production. Indeed, the one question that the LI director typically asks production personnel is whether they know how much it costs to repair the item(s) for which they have maintenance responsibility. Because effectiveness is still a factor in garnering sales revenue and DMIF budget allocations, it cannot be totally ignored. Nevertheless, as the LIT division chief observed, if the right number of people are assigned to a workload, effectiveness will generally take care of itself.

Managerial Constraints

As was the case at WR-ALC, at OO-ALC the DOD hiring freeze, early retirements, and reductions in force (RIFs) have impacted the experience level of the workforce, particularly in the scheduling and planning career fields. In addition, because a number of materiel controller slots have been eliminated, production personnel are now having to order and track parts themselves. The implementation of an LIL PAT recommendation to develop materiel support teams would do much to resolve the problems associated with the manpower shortfalls in scheduling and planning. A materiel support team would be structured for management of a group of NSNs common to a weapon system and would consist of

logistics managers, inventory (item) managers, engineers, technical managers, and materiel managers. Technical managers' skills and knowledge would span those of equipment specialists and production planners. The materiel manager position would combine the skills series for production management specialist, materiel controller, shop floor scheduler, and supply inventory management specialist.

Of course, establishment of the technical manager and materiel manager positions would require OPM (Office of Personnel Management) approval and the changing of several personnel policies. However, it seems that the new materiel support team structure is much better suited to AFLC's product directorate organization and to meeting the demands imposed by competition. These demands are causing the greatest workload increase in LIL's engineering unit. Besides having to update work documents, the engineers are responsible for formulating statements of work (SOWs), requests for proposal (RFPs), and production bids and for estimating competitors' overhaul costs. Unfortunately, LIL engineers have little or no experience in cost estimation and the preparation of SOWs, RFPs, and bids. Nonetheless, a teamwork approach like that inherent in the materiel support team structure could be employed to reduce the burden on engineering and improve the division's ability to compete effectively.

Another policy change that would enhance OO-ALC's competitive posture and save the center more than $4 million

annually is the fixing of all parts coded for field level repair. An F-16 external lighting panel and an F-4 avionics cooling duct can be used to illustrate the potential savings. By taking one hour to replace a $240 transformer on the $1790 lighting panel, $1500 can be saved. The cooling duct costs $1740 to purchase, but can be fixed in three hours at a labor cost of $150, which results in a total savings of $1590. Although Air Force and AFLC regulations require the repair of parts coded for field level repair, when these parts are found defective at the depot, they are typically routed to salvage instead of a repair backshop. At least half of these parts could be repaired, but DMIF work funding policies and procedures discourage these type of repairs. The depot supply system (D0035K) considers these parts disposable and does not provide manhours or dedicated funding for field level repairs. To resolve these problems, LA's repair versus buy PAT has recommended changing the supply software for items coded for field level repair in the repair cycle and make them accountable. This PAT also recommends providing manhours to the backshops for repair of these items and establishing repair shop capability and routing for these repairs.

Logistical Constraints

While parts/material availability was cited as the most critical constraint by the landing gear division chief and nearly every LIL production supervisor, the two top concerns

of the technical repair center division chief were management of profit/loss and the way workload negotiations are conducted. To help his supervisors understand financial reports, the LIT division chief is ensuring that LIT's unit and subunit chiefs receive training on 15 critical depot maintenance data systems. This training is in addition to the training these supervisors have received on the use of the in-house financial spreadsheet which the LA, LI, and FM directorates have developed. To monitor profit/loss status, LIT requires units to brief this information at the division's weekly staff meeting and has assigned two people to monitor division finances on a full-time basis.

Because 90 percent of LIT's workload is managed at other ALCs, it is understandable that workload negotiation is one of this division chief's main concerns. According to the LIT chief, AFLC funding changes and the inability of item managers to input requirements to the D041 system on time are responsible for many of the fluctuations and uncertainty in negotiated workloads. He said that the negotiated numbers for a quarterly workload are not often firm until the third week of a quarter. To provide for better long-term planning, this division chief proposes negotiating exchangeable workloads on a yearly basis.

The MISTR negotiation process and the local manufacturing process displayed in Figures IV-49 and IV-50 are two of the processes for which LIL's materiel supportability PAT developed flow charts. This PAT was

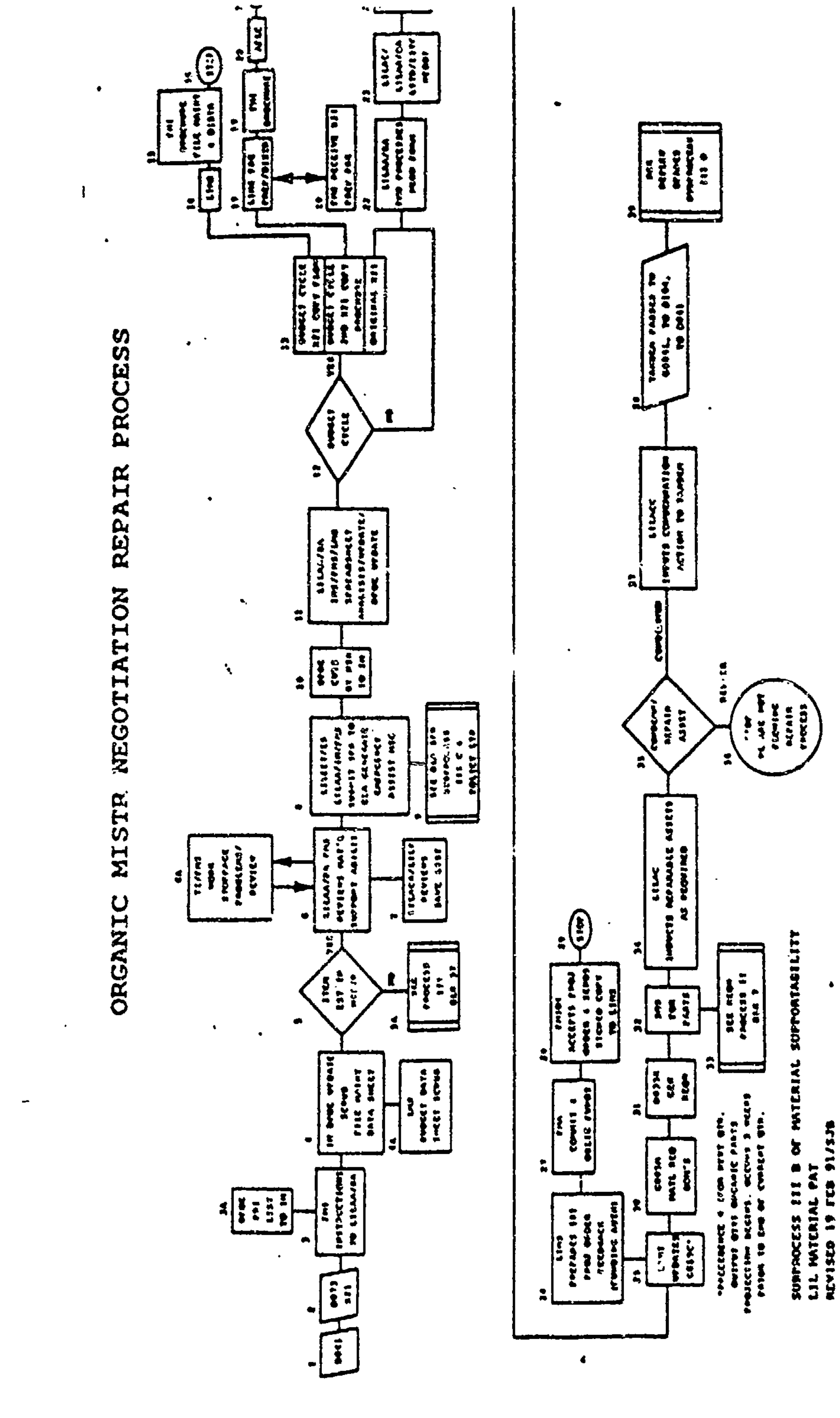


Figure IV-49. Organic MI~~STR Work~~load Negotiation Process

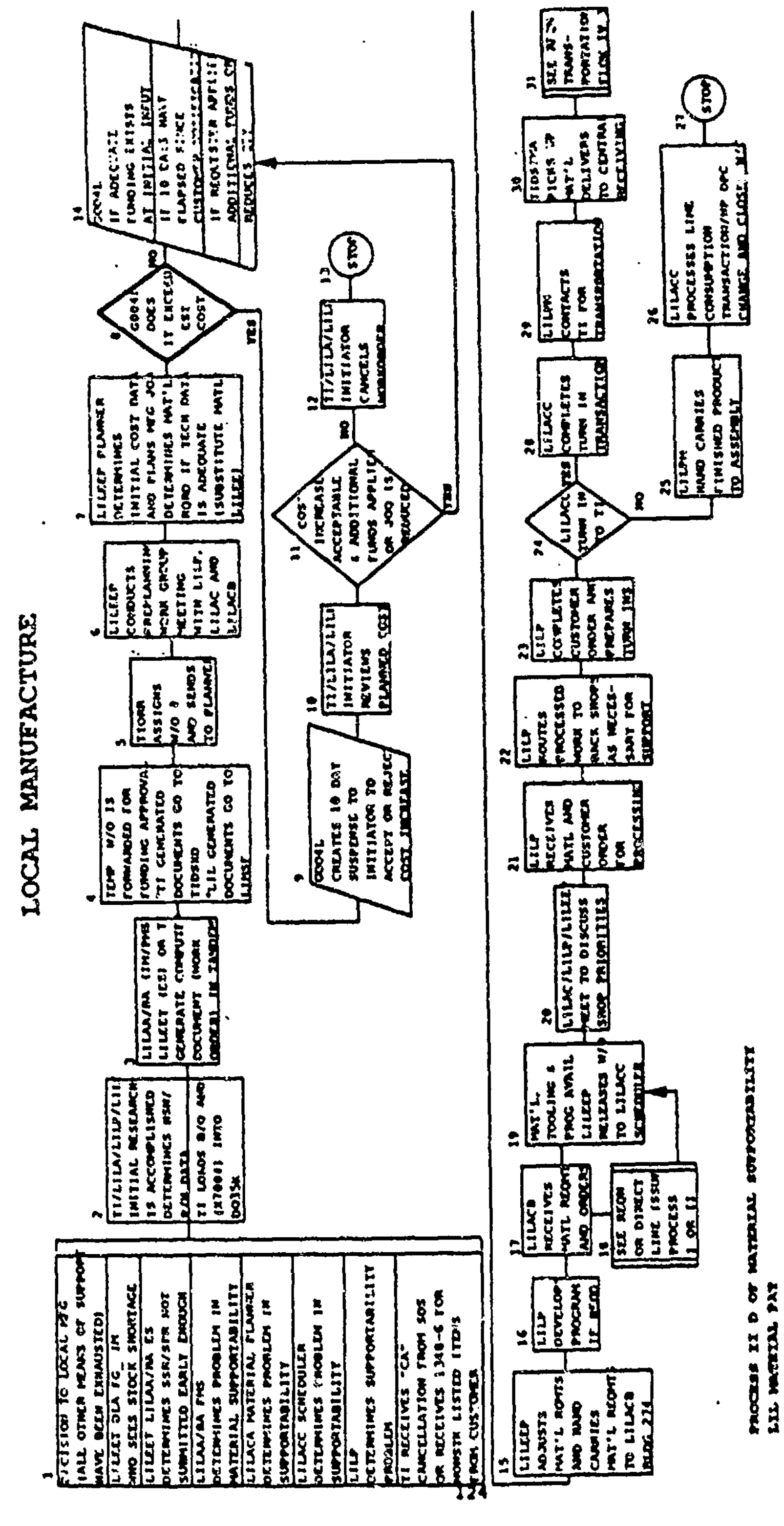


Figure IV-50.—~~Local~~ Manufacture Process

tasked to determine why material shortages are the single largest problem affecting LIL throughput and to look at an organizational structure for facilitating process improvements for materiel supportability. The team's recommendations for a new organizational structure were discussed in the previous section. Provided the materiel support team members are held accountable and their performance appraisals are tied to weapon system supportability, this new structure will be a viable force in resolving parts problems. The LIL engineering chief and the LIL lead scheduler believe that the AFLC goal of personal accountability is one of the keys to improving materiel support. Bar coding would also help greatly in scheduling and tracking items on the shop floor. Lack of an automated tracking system and the need to develop schedules manually were cited as the LIL scheduling section's most critical problems. Additionally, the lead scheduler observed that throughput could be increased by employing buffer management, reducing machine setup times, and operating bottleneck machines 24 hours a day.

F-16 Depot Maintenance

Ogden ALC, Utah

F-16 Program Overview

With nearly 500 F-16 C and D models still slated for production and a number of the older A and B models beginning to show structural deficiencies, OO-ALC's F-16 workload should continue to grow for several more years. By

the end of FY 1992, this workload is expected to comprise 70 percent of the center's total aircraft workload. More than two-thirds of the Air Force's F-16 fleet is assigned to Air National Guard units and Tactical Air Command (TAC) wings. The rest of the F-16s are located at other bases in the United States, Europe, and the Pacific region. Additionally, the aircraft directorate (LA) has system program management responsibility for 26 Navy F-16s and approximately 950 F-16s belonging to 14 foreign countries. The locations of the United States Air Force (USAF) units, or customers, for which OO-ALC performs F-16 depot maintenance are listed in Figure IV-51.

Aircraft Directorate Overview

Customer commitment is the cornerstone of OO-ALC's vision statement. The chart in Figure IV-52 illustrates how the aircraft directorate's (LA's) six goals align with the depot's four areas of focus to achieve the center vision. LA employs more than 2900 personnel and is divided into the following eight divisions: F-16 system program management (SPM), F-4 system program management, combat logistics support, international, program management, customer services, aircraft operations (LAO), and technical repair (LAR). Figure IV-53 provides an organizational chart for the aircraft directorate. Although all LA divisions except the F-4 SPM division support F-16 depot maintenance, this case will focus on the two divisions responsible for aircraft and component repair, LAO and LAR. Seventy

Air Forces Europe

Hahn AB

Ramstein AB

Spangdahlem AB

Torrejon AB

Pacific Air Force

Eielson AFB

Kunsan AB

Misawa AB

Osan AB

Tactical Air Command

Hill AFB

Homestead AFB

Luke AFB

Macdill AFB

Moody AFB

Nellis AFB

Shaw AFB

Air Force Systems Command

Edwards AFB

Eglin AFB

Air National Guard

Andrews AFB

Atlantic City

Burlington

Capital

Dannelly Field

Duluth

Ellington

Fargo

Fresno

Ft Smith

Great Falls

Hancock Field

Hulman

Jacksonville

Kelly AFB

Kingsley Field

McConnell AFB

McEntire

Niagara Falls

Richmond

Selfridge AFB

Tucson

Figure IV-51. Locations of F-16 USAF Customers

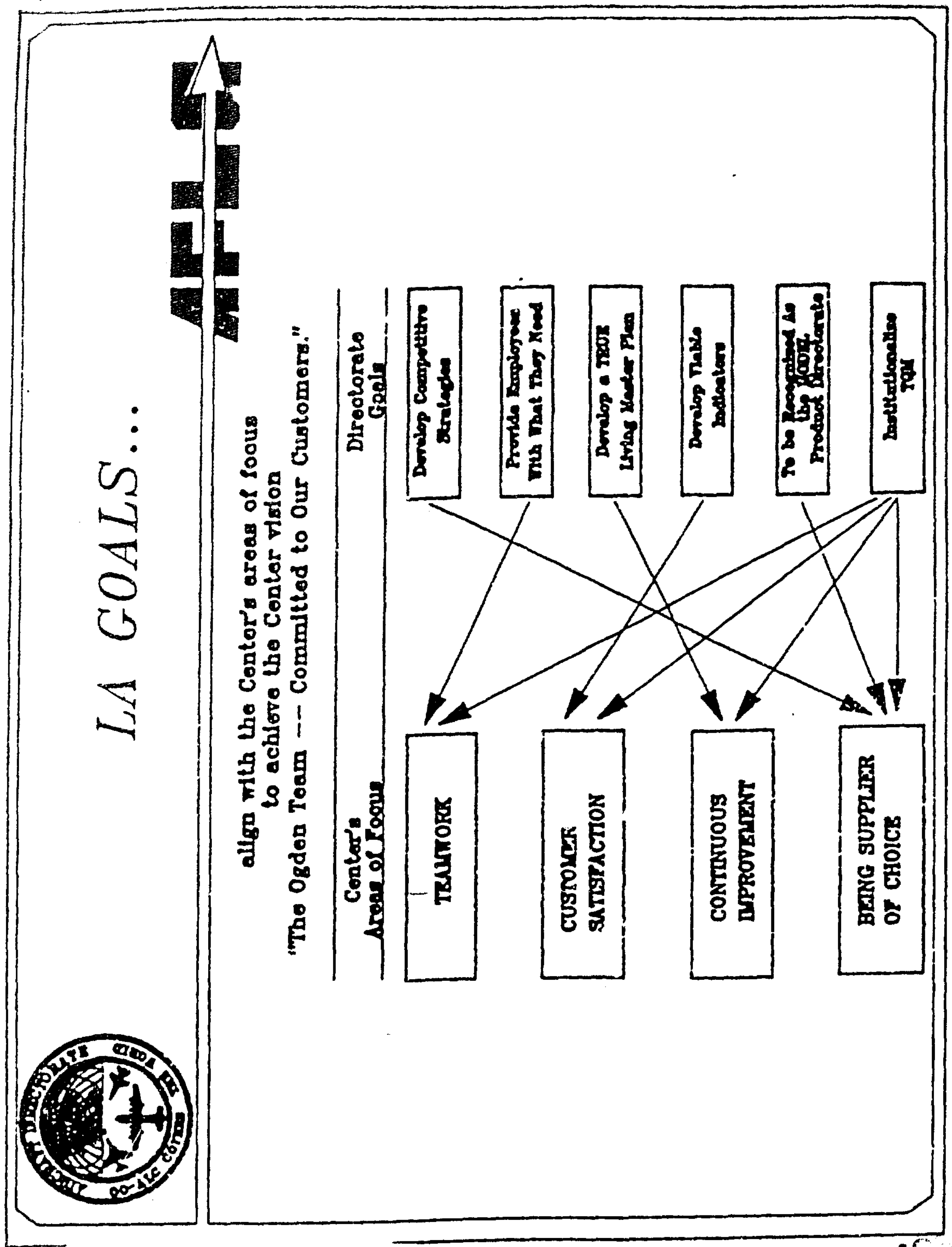


Figure IV-52. OO-ALC Aircraft Directorate Goals

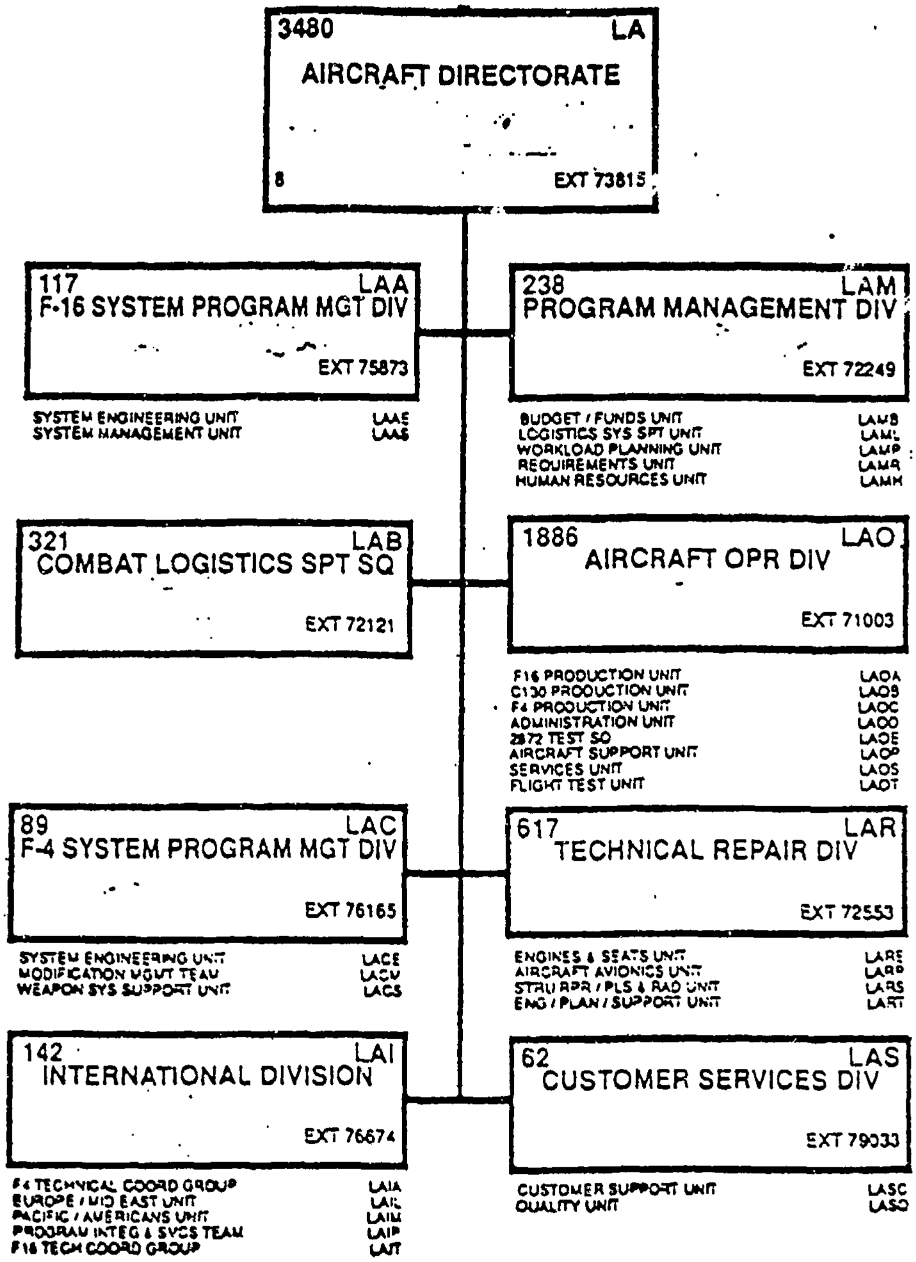


Figure IV-53. OO-ALC Aircraft Directorate Organizational Chart

percent of LA's total personnel are direct laborers assigned to these latter two divisions.

Before looking at LAO and LAR, the aircraft directorate's innovative QP4 center will be briefly examined. LA has a conveniently located walk-in quality center that helps shop floor personnel solve problems. All problems are either researched or turned into formal suggestions. By flowing the suggestion process (see Figure IV-54) and assigning five permanent suggestion evaluators, LA has reduced suggestion approval flow time from 180 days (using 83 part-time evaluators) to 55 days. This reduction is all the more remarkable given the fact that the QP4 center follows regulations and does not approve suggestions until they have been implemented. For three years the quality center has also operated an internal customer satisfaction project (ICSP). This program allows for the identification of internal customer dissatisfaction with products/materials between divisions within LA. The 51 ICSPs generated in 1990 resulted in the resolution of several internal quality problems, including changing engineering drawings to allow an F-16 fuselage closure skin to fit properly.

Aircraft Operations Division Overview

Organization and Goals

The aircraft operations division (LAO) contains three production units, a test squadron, an administration unit, an aircraft support unit, a services unit, and a flight test

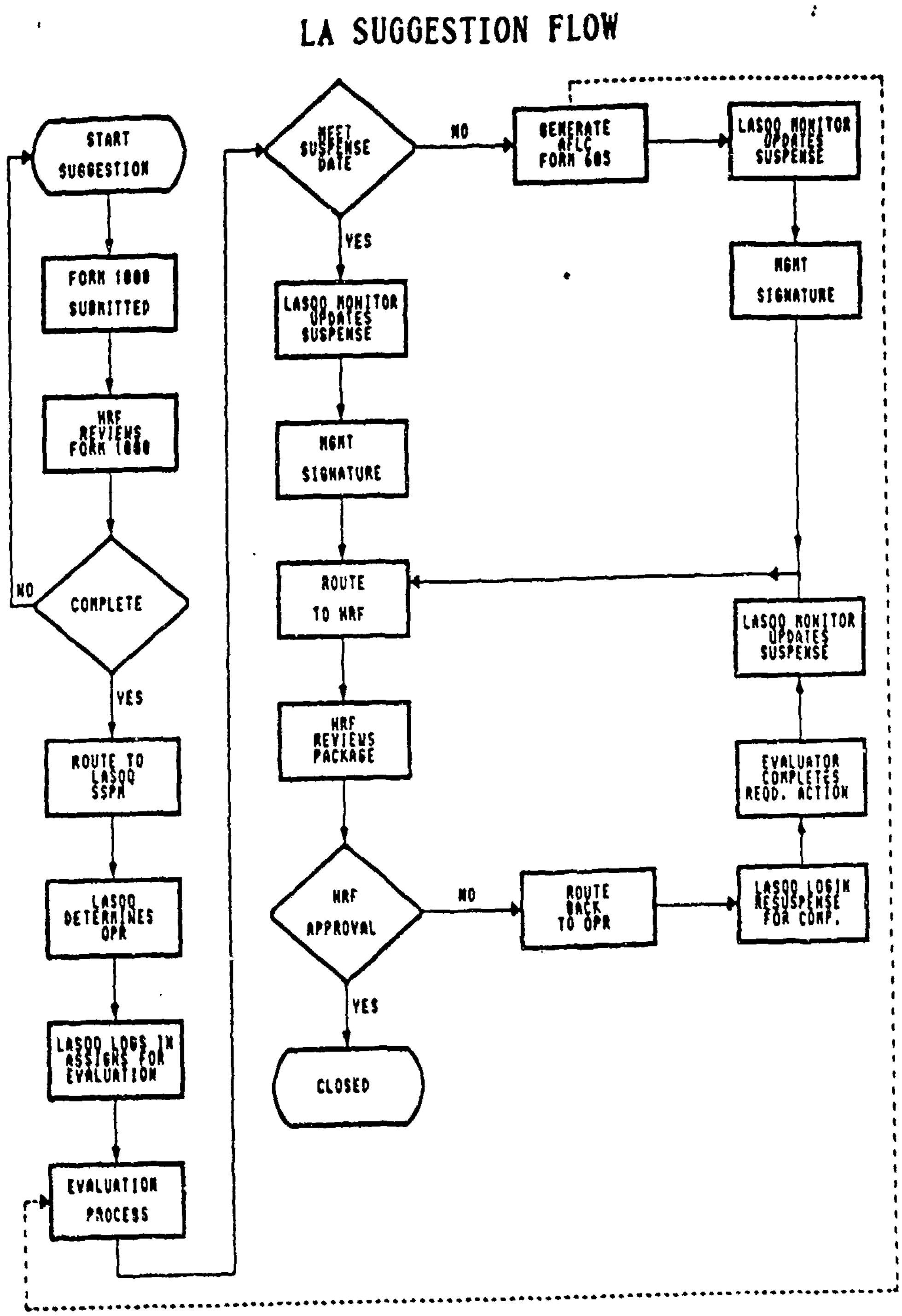


Figure IV-54. LA Suggestion Flow

unit. The latter three units perform incoming (pre-dock) and outgoing (post-dock) inspections and maintenance on all F-4, F-16, and C-130 aircraft. Direct labor workers account for 1400 of LAO's 1670 personnel. The division operates two full eight-hour shifts and a partial graveyard shift of 80 people, Monday through Friday. Approximately 530 employees, including 57 planners, schedulers, and other indirect workers, are assigned to the F-16 production unit. Each production unit has its own planners and schedulers, so these individuals now identify themselves more closely with production personnel than they did prior to the reorganization. Figure IV-55 outlines LAO's mission and goals and includes a copy of the ICSP (Internal Customer Satisfaction Project) submission form.

Workload

Scheduled modifications, rather than PDM, make up 95 percent of the F-16 workload. Unscheduled maintenance accounts for the remaining five percent. The majority of the modifications are performed on a particular block of aircraft, instead of on the entire fleet, and generally run for two to three years. As a result, the F-16 fleet is highly compartmentalized, and F-16 planning and material support are constantly a challenge. Though approximately 40 time compliance technical orders (TCTOs) are currently in progress, the operational capabilities upgrade (OCU) and air defense fighter (ADF) TCTOs are among the most important modifications. The ADF program involves modifying several

L A O
MISSION STATEMENT

" THE MISSION OF THE AIRCRAFT OPERATIONS DIVISION IS TO COMPETITIVELY PRODUCE WORLD CLASS QUALITY AIRCRAFT THAT EXCEED OUR CUSTOMERS' EXPECTATIONS. "

GOALS

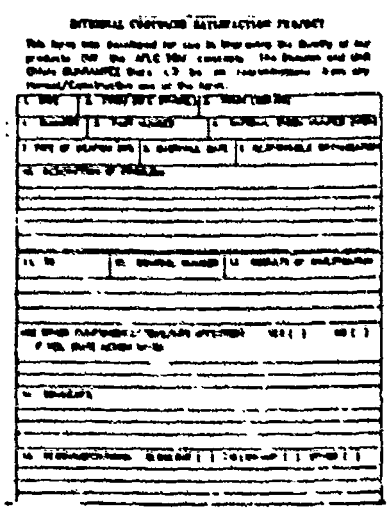
COMPETITIVE

ESTABLISH A BUSINESS OFFICE FOR THE PURPOSE OF:
- a. Identifying potential customers, their needs, requirements, and objectives.
- b. Develop marketing strategies based on requirements.
- c. Develop pricing, cost, and resources based on requirements.

PROFIT/LOSS
- a. Develop an accounting system that will provide a profit/loss status on a timely basis.

SCHEDULE
- a. Provide the aircraft to the customer on or ahead of schedule.

DEVELOP VALID INDICATORS
- a. To provide indicators that reflect the status of the aircraft in the maintenance cycle.



QUALITY

CUSTOMER
- a. Identify internal and external customers.
- b. Identify needs and expectations.

REWORK
- a. Identify (admit) and correct
- b. Reduce rework

RELIABILITY/MAINTAINABILITY
- a. Set standard
- b. Develop a system to measure/track

FEEDBACK
- a. Timely/accurate customer feedback

SUPPLIERS
- a. Identify suppliers internal and external
- b. Provide suppliers with LAO requirements
- c. Provide feedback on products/services

Figure IV-55. LAO Mission and Goals

GOALS
PROCESS IMPROVEMENT

PRIORITIZED LISTS
- a. Develop prioritized lists of processes based on quality cost reduction and productivity gains.

TOP-DOWN COMMITMENT
- a. Total manager commitment at all levels.
- b. Manager involvement through participation.

FACILITIES / EQUIPMENT
- a. Available and reliable

DEVELOP VALID INDICATORS
- a. Identify pulse points
- b. Collect / analyze data

DECENTRALIZE/AUTONOMOUS/ACCOUNTABLE

WORK FORCE

TRAINED / SKILLED
- a. Provide necessary training

MOTIVATED
- a. Employee participation
- b. Recognition
- c. Empower work force to challenge business as usual

TRAIN MANAGERS
- a. Train and evaluate managers
- b. Let them do their job (Reduce micro-management)

TEAM BUILDING
- a. Learn about and plan for Quality
- b. Find solutions
- c. Remove barriers and promote partnership

Figure IV-55. LAO Mission and Goals

hundred F-16s into primary intercept weapon system capable aircraft for the Air National Guard. The OCU modification concerns the installation of several radar and avionics system improvements on a number of older F-16 A and B models.

Of 273 F-16s scheduled for depot maintenance at OO-ALC during FY 1992, 167 will receive the OCU TCTO and 39 F-16s will be modified into air defense fighters. Depending on the modifications that must be installed on an aircraft, F-16 depot maintenance averages 25 to 110 flow days. The basic flow for this process is outlined in Figure IV-56 and is quite similar to the PDM flows previously seen. The incoming/disassembly, flight test, and modification/depot repair phases correspond to the C-130 pre-dock, post-dock, and mod-dock phases.

Technical Repair Division Overview

Goals, Organization, and Workload

The technical repair division's (LAR's) five goals and 32 objectives displayed in Figure IV-57 closely parallel the LA goals. The division's work center teams are a prime example of how the AFLC goal of people empowerment can be achieved. LAR's 576 employees are assigned to eight work center teams spread among four units - technical support, engines, aircraft avionics, and structural repair and plastics. The work center teams, which consist of planners, schedulers, materiel controllers, and production workers, are under the direction of the unit chiefs and are

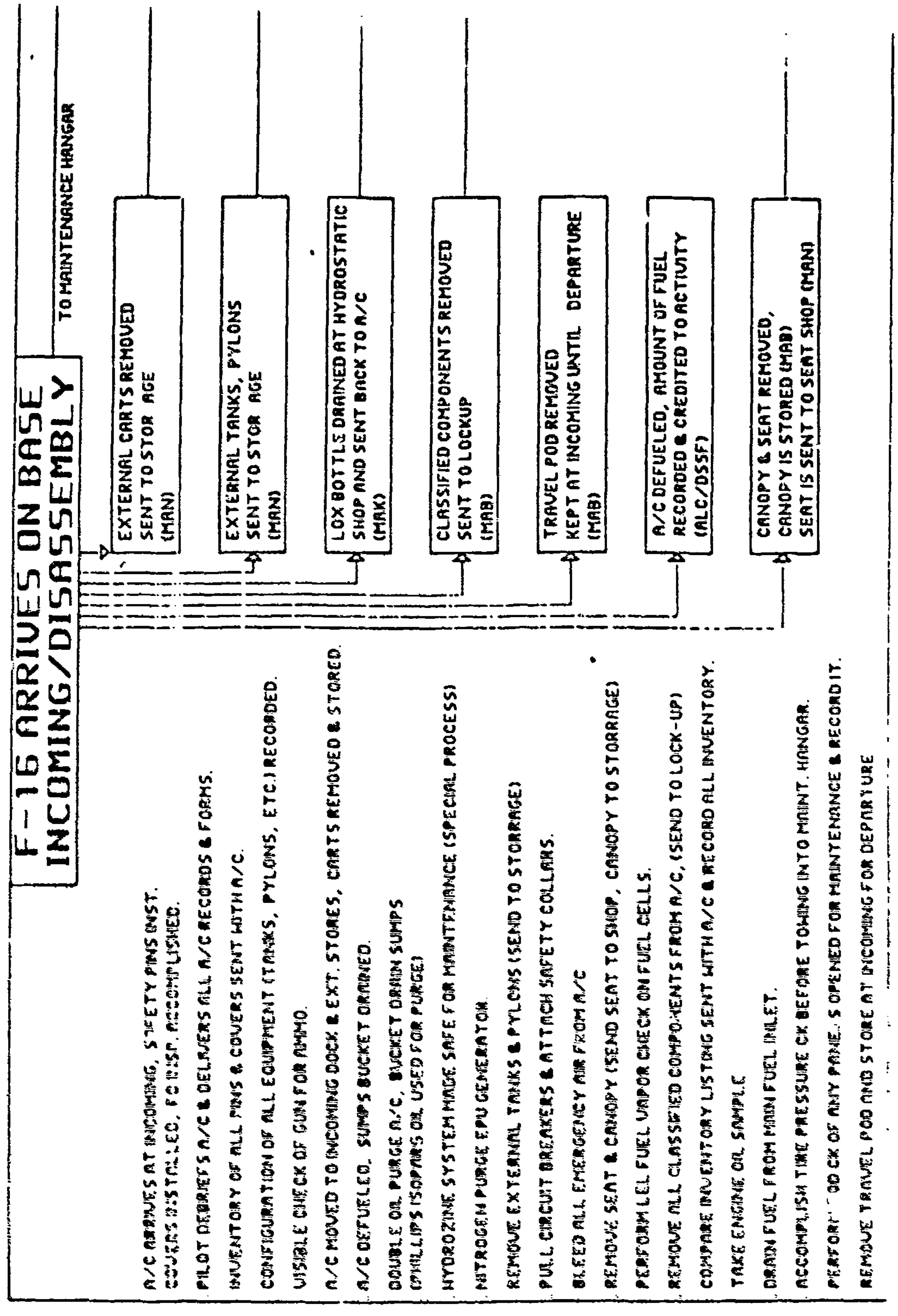


Figure IV-56. F-16 Depot Maintenance Flow

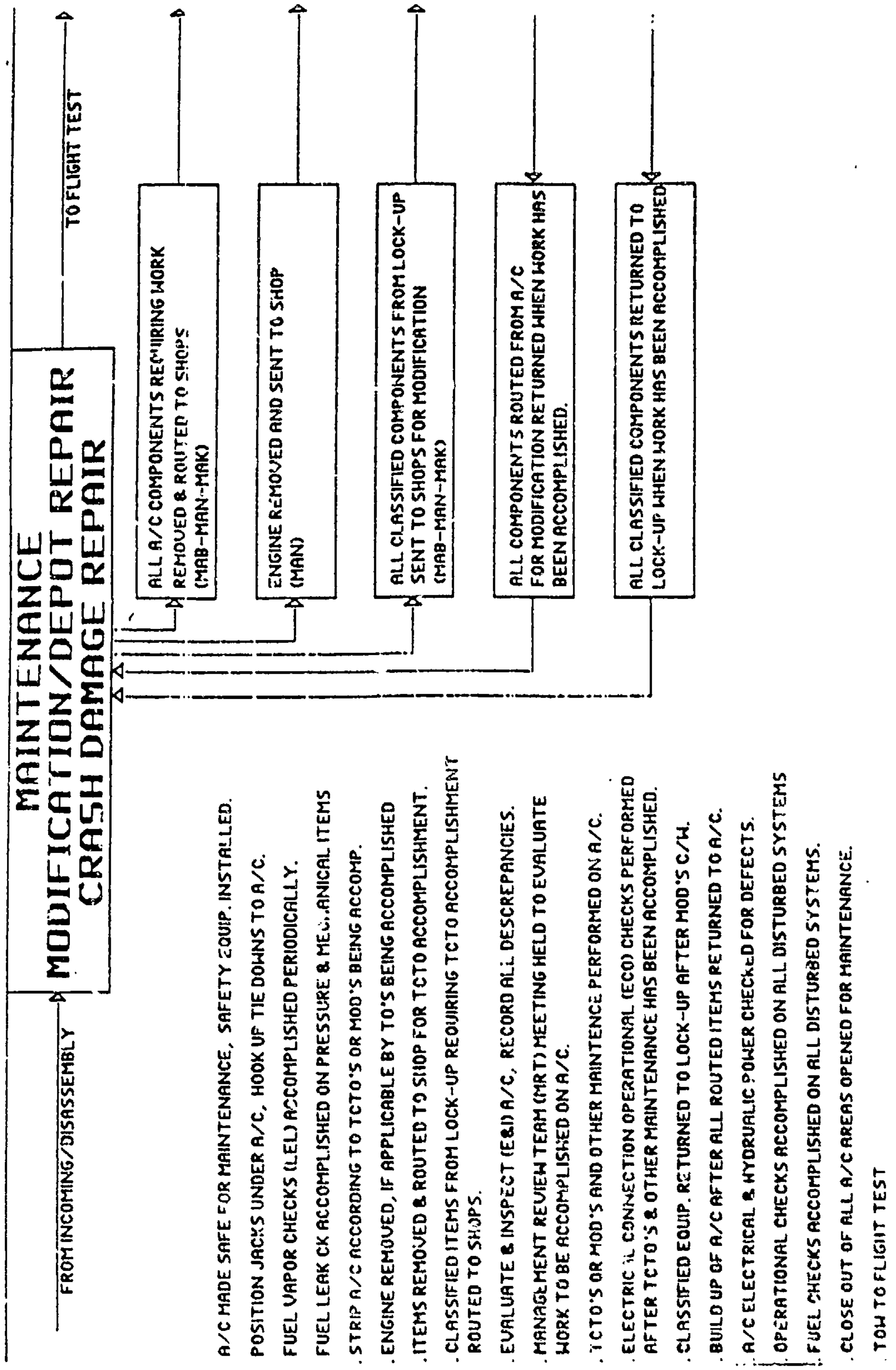


Figure IV-56. F-16 Depot Maintenance Flow

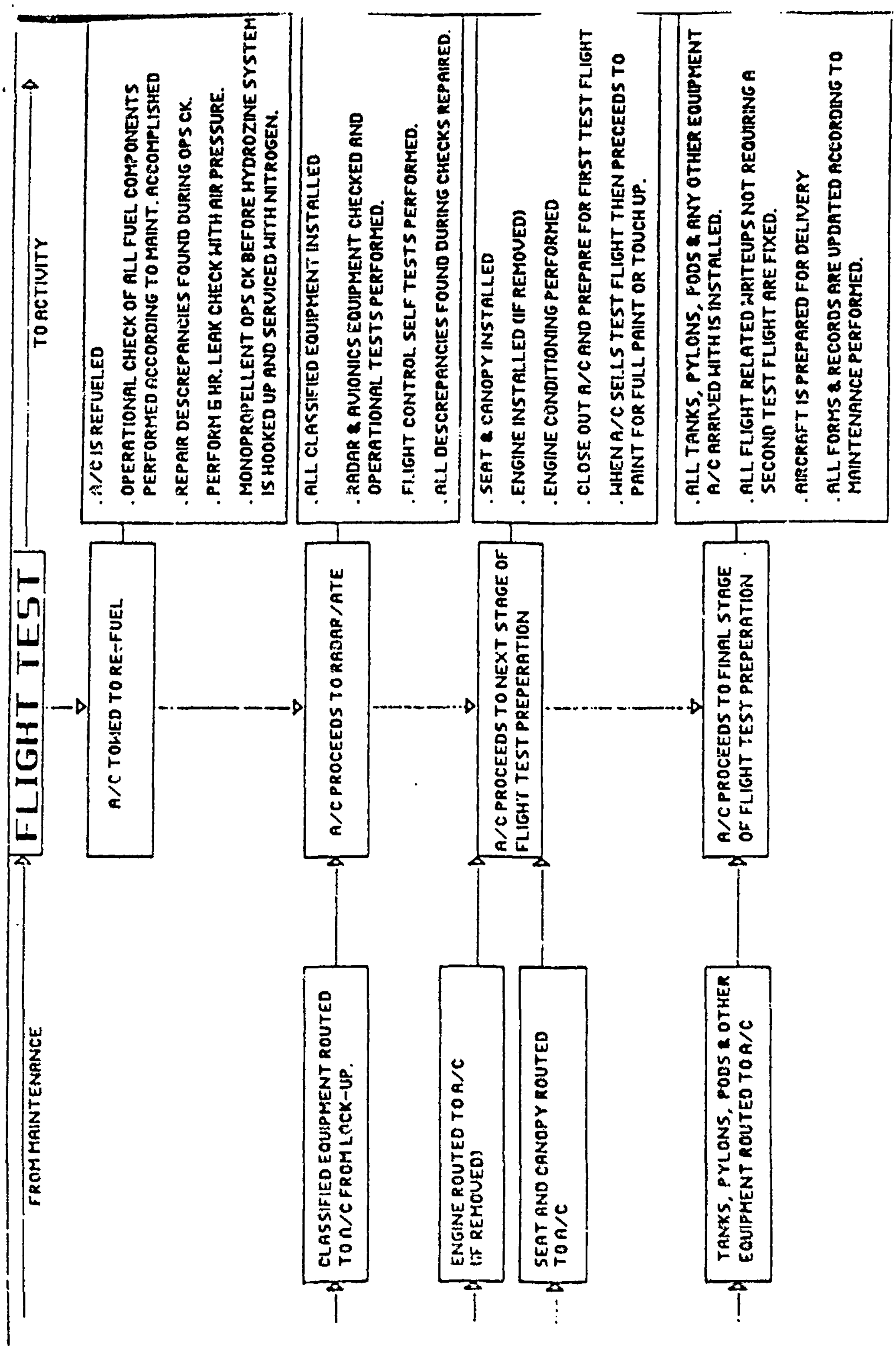


Figure IV-56. F-16 Depot Maintenance Flow

TECHNICAL REPAIR DIVISION

MISSION STATEMENT

The Technical Repair Division provides quality PDM support for the F-4, F16, and C-130 Aircraft Operations Division and worldwide support for structural repair of component parts and assigned electronic aircraft systems which consistently exceed customer requirements and expectations.

GOALS

* Provide unparalleled support through total quality management
* Develop strategies to ensure workload is fully supportable
* Utilize the full potential of the workforce
* Develop a living master plan
* Successfully implement MRP II

1. Provide unparalleled support through total quality management by:

   A. Ensuring all personnel are aware of their respons-ibilities concerning total quality management and the privileges offered by the Quality Bill of Rights:
      -- Establish base line of knowledge of the Bill of Rights by conducting a survey
      -- Reacquaint employees with the Quality Bill of Rights by issuing each employee a card stating the Bill of Rights, if necessary
      -- Conduct another survey in six months

   B. Empowering employees by motivating, changing attitudes and habits, educating, and instilling pride in workmanship:
      -- Identify outstanding personnel through awards and recognition

   C. Ensuring only quality products/services are delivered to our customers:
      -- Provide 100% guarantee on our parts and services
      -- Get acquanted with internal and external customers and their requirements
      -- Establish a customer relations program (see attached proposed form and OI for use with internal customers)

   D. Consistently meet or exceed customers needs and expectations by:

Figure IV-57. LAR Mission and Goals

-- Ensuring all customer requirements have been met
-- Survey customers on satisfaction with product/service

E. Furnishing products and services on time and at the lowest possible cost:
-- Review and validate labor and material standards
-- Make monthly comparisons of cost by monitoring profit and loss by RCC
-- Constantly reviewing and improving our processes to ensure competitiveness

2. Develop strategies to ensure workload is fully supportable by:

A. Taking advantage of available materials
-- Utilize in stock/excess materials to the fullest

B. Making material substitution
-- Make full use of our material and systems engineers
-- Review MIL specs for alternate materials

C. Developing faster and more effective procurement processes
-- Establish a materials purchasing cell or incorporate a cell concept within our workcenter teams
-- Requirements purchasing contract for large unprogrammed workloads

3. Utilize the full potential of the workforce by providing:

A. Team support through a total workcenter team concept
-- Establish workcenter teams and define workloads and responsibilities as necessary

B. Specialized training
-- Identify training needs and requirements
-- Provide single point of contact for training
-- Provide training as soon as possible upon request

C. Adequate systems access for all required personnel

-- Provide systems terminal access in the employees immediate work area as required by job responsibilities

Figure IV-57. LAR Mission and Goals (Cont'd)

D. Proper tools and tooling
   -- Provide ergonomically acceptable tools whenever and wherever possible

E. Safe, productive work environments
   -- Implement ergonomic technology

4. Develop a living master plan by:

   A. Providing total support required by each workload
      -- Evaluate processes and be certain adequate tooling is available or can be acquired
      -- Review material requirements well in advance to ensure availability when needed

   B. Maintaining flexibility to accommodate existing and new workloads
      -- Establish dual skills for personnel and allow movement as necessary to accommodate workload requirements to assure effective utilization of human resources

   C. Ensuring facilities and capital investments provide support for as many workloads as possible
      -- Extend preplanning processes to encompass existing and future potential weapons system workloads
      -- Incorporate ideas for future workload or facility expansion into new facility design

5. Successfully implement MRP II by:

   A. Continuing support and pre-implementation of MRP II philosophy and the DMMIS system
      -- Implement MRP II processes into the current work environment whenever and wherever possible
      -- Ensure material and labor standards are converted to the proper format for input to new DMMIS systems and software

   B. Motivating personnel by providing needed training and complete understanding of the DMMIS project
      -- Ensure on-going training is accomplished to ensure readiness upon program implementation

Figure IV-57. LAR Mission and Goals (Cont'd)

held responsible for everything that affects their workload. The teams make their own budget, negotiate their own workload, and research their own QDRs. With just over 100 indirect labor employees in the division, LAR is formulating a job description for a production support specialist (planner/scheduler/materiel controller) so that production support can be provided with the fewest people possible. In addition, the alignment of scheduling and planning around end items and weapon systems, rather than repair shops, has eliminated many internal scheduling bottlenecks. The division is using its work center teams to implement TQM. For example, a team in the structural repair and plastics unit recently employed time studies and process flow charts to revise the F-16 wing repair process and reduce the labor standards for this process by 50 percent.

The duty hours for the different work center teams vary. As a rule, the engines and structural repair units work a ten-hour shift four days a week, while the avionics unit operates three eight-hour shifts, Monday through Friday. Scheduled repair of structural items and avionics components represents approximately 60 percent of LAR's workload. Nearly all of the remaining 40 percent, which is unscheduled maintenance, involves the engines and plastics workloads. Overall, at least half of the division's workload is in support of the F-16 aircraft. Because the avionics unit is currently assuming repair capability for F-16 C and D model avionics items from a private contractor,

this unit is probably the one in LAR that is the most critical for F-16 depot maintenance.

Avionics Unit Overview

More than half of the avionics unit's (LARP's) 262 employees repair F-16 avionics components. As illustrated by Figure IV-58, the unit's two subunits are divided into 10 smaller work teams. While the unit performs depot repair on all F-16 SRUs, it also handles the depot repair of a number of LRUs and SRUs installed on other weapon systems (see Figure IV-58). Scheduled maintenance through the MISTR and DRIVE programs accounts for 95 percent of LARP's workload. Avionics components for F-4s and all other aircraft, except the F-16, are scheduled on a quarterly basis through the MISTR program. Under the DRIVE concept, F-16 avionics items are scheduled once every two weeks. Though DRIVE offers general guidelines for the entire quarter, there is a new window every two weeks. As a result, the avionics unit has been forced to reduce machine setup times and develop a more flexible, multi-skilled workforce. DRIVE is aimed at filling MICAP orders for avionics parts, and item managers contend that it does provide better customer support. Consequently, LARP is trying to get approval for using DRIVE to negotiate all their workloads.

Competitive Edges

Because, at the directorate level, the same sets of competitive edge rankings were used for both the F-4 and F-16 cases, the reader should refer to the F-4 case for

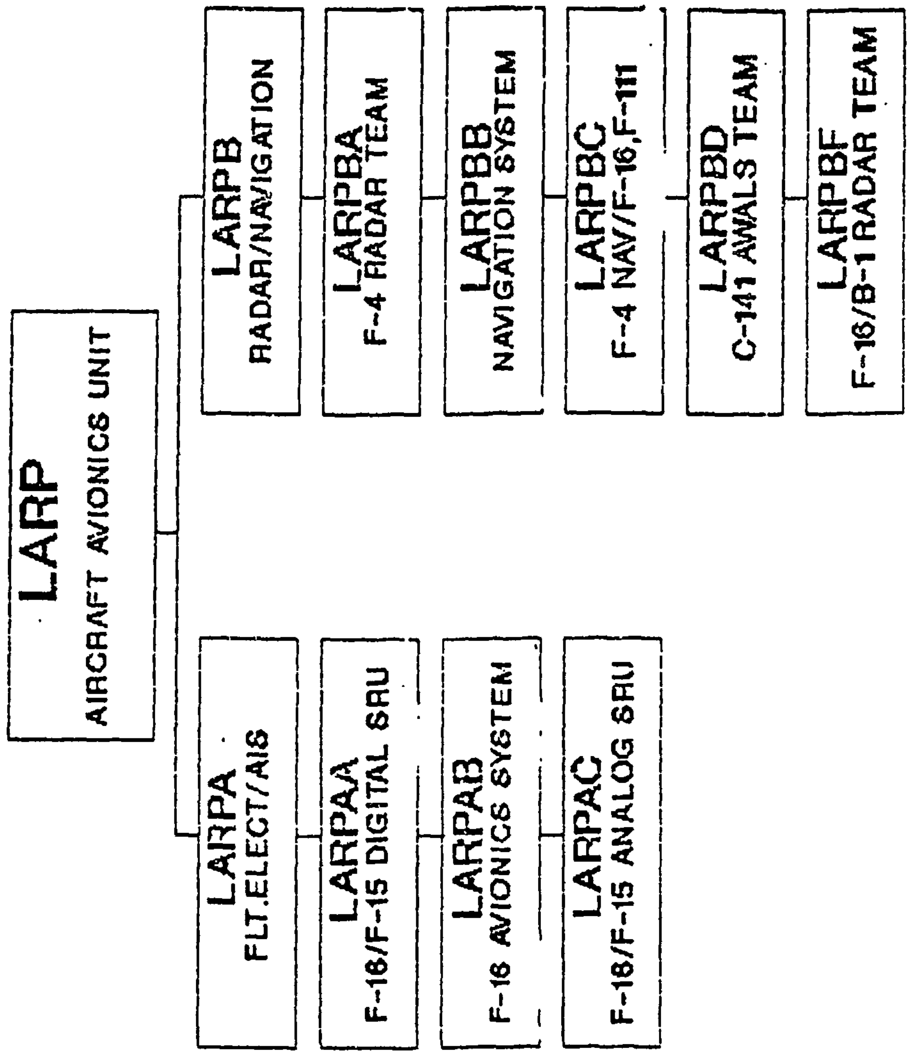


Figure IV-58. OO-ALC LA Avionics Unit Organizational Chart

comments concerning directorate rankings. Although the LAO and LAR division rankings are also part of both cases, this case replaces the LI landing gear division rankings with those from the LI technical repair center division (LIT). In both the objectives and criteria categories, the three division chiefs rank quality and cost among the most critical competitive edges. However, while the LIT and LAR chiefs consider flexibility to be the least important edge, the LAO chief ranks it as the third most critical edge, by objectives. Given the dynamic nature of the F-16 workload, this ranking is quite logical. By criteria, all these managers ranked flexibility last. Whereas the LAO and LIT criteria rankings were fairly similar, the LAR chief included lead time among the top three competitive edges. Figures IV-59 and IV-60 contain the F-16 directorate and division rankings.

As with the F-4 rankings, the F-16 unit and subunit competitive edge rankings illustrated in Figure IV-61 exhibit the strongest agreement of all four organizational levels in both the objectives and criteria categories. Like their F-4 counterparts, F-16 unit and subunit supervisors ranked lead time, innovation, and flexibility as the three least critical competitive edges and quality, cost, and delivery as the three most important edges. Except for the reversal of flexibility and innovation, the rank order of the unit rankings by objectives and the subunit rankings, by

Aircraft Directorate (n=1)		
Rank Order	By Objectives	By Criteria
1	Quality	Quality
2	Flexibility	Cost
3	Innovation	Delivery
4	Cost	Flexibility
5	Lead Time	Innovation
6	Delivery	Lead Time

Commodities Directorate (n=1)		
Rank Order	By Objectives	By Criteria
1	Quality	Quality
2	Flexibility	Flexibility
3	Innovation	Innovation
4	Lead Time	Lead Time
5	Delivery	Delivery
6	Cost	Cost

Figure IV-59. Directorate Competitive Edge Rankings

Aircraft Operations Division (n=1)		
Rank Order	By Objectives	By Criteria
1	Cost	Cost
2	Quality	Quality
3	Flexibility	Delivery
4	Delivery	Innovation
5	Innovation	Lead Time
6	Lead Time	Flexibility

Aircraft Technical Repair Division (n=1)		
Rank Order	By Objectives	By Criteria
1	Quality	Quality
2	Lead Time	Lead Time
3	Cost	Cost
4	Delivery	Delivery
5	Innovation	Innovation
6	Flexibility	Flexibility

Commodities Technical Repair Center Division (n=1)		
Rank Order	By Objectives	By Criteria
1	Quality	Quality
2	Cost	Cost
3	Delivery	Delivery
4	Lead Time	Lead Time
5	Innovation	Innovation
6	Flexibility	Flexibility

<u>Figure IV-60</u>. Division Competitive Edge Rankings

Aircraft and Commodities Unit Chiefs (n=4)				
Rank Order	By Objectives	Ranking	By Criteria	Ranking
1	Quality	2.75	Cost	2.50
2	Cost	2.75	Delivery	2.75
3	Delivery	3.00	Quality	3.00
4	Lead Time	3.50	Lead Time	4.00
5	Flexibility	4.25	Flexibility	4.00
6	Innovation	4.75	Innovation	4.75

Aircraft and Commodities Subunit Chiefs (n=6)				
Rank Order	By Objectives	Ranking	By Criteria	Ranking
1	Quality	1.43	Quality	1.29
2	Cost	2.57	Cost	2.86
3	Delivery	2.43	Delivery	2.57
4	Lead Time	4.14	Lead Time	3.43
5	Innovation	5.00	Innovation	5.00
6	Flexibility	5.43	Flexibility	5.14

Figure IV-61. Competitive Edge Rankings by Unit Chiefs and First-Line Supervisors (Subunit Chiefs)

objectives and by criteria, is identical. By criteria, unit chiefs consider cost to be the most critical competitive edge. In general, F-16 unit and subunit chiefs place slightly more importance on cost than do F-4 supervisors at these levels.

Performance Criteria

The aircraft directorate holds weekly production and DMIF profit/loss status meetings with its division chiefs. The production meeting primarily looks at scheduled production versus actual production for the directorate's aircraft and exchangeable items. At the profit/loss review, the center's in-house financial spreadsheet is used as the basis for discussing the reasons behind various operating expenses and profit/loss showings of LA's RCCs (Repair Cost Centers). In many cases this spreadsheet details expenses down to the six-digit level, or the level just below subunit level. Twice a month the aircraft directorate also conducts a management review with each of its divisions. The LAO and LAR management indicators outlined in Figures IV-62 and IV-63 cover many of the same topics, such as training, production status, TDY expenses, and overtime. Because the aircraft division is not required to present a formal briefing to the center commander on a regular basis, the LA management review indicators may be considered to be a compilation of the indicators used by its divisions. Of course, when LA's directors visit the F-4 and F-16 SPM divisions, engineering, contracting, and item management

1. LAO TDY - Budgeted and actual year-to-date TDY expenses for the categories of administration, training, and rental car

2. G&A Expenses - Budgeted and actual year-to-date general and administrative expenses for the latest month by nine categories

3. LAO Sales - Number of hours sold, hours earned, and aircraft sold for each month of the current and previous fiscal year

4. LAO Profit (Loss) - Revenue, costs, and profit/loss for each month of the current fiscal year for the LAO division

5. LAO Overtime - LAO's direct and indirect overtime for the most recent month and the year to date

6. New Employee Bypass Testing - Number of employees tested and scheduled and number of failures, by course, for the latest month

7. Recertification - Number of employees recertified, by type of training and by LAO unit, for the latest month

8. General Training - Number of slots required and received and employees trained and awaiting training, by course, in latest month

9. Training Initiatives - Recent training accomplishments

10. Manpower Status - Number of personnel currently authorized and assigned for the LAO staff and units according to the following categories: Direct, indirect, officer, enlisted, and O&M

11. LAO Sick Leave - Percentage of sick leave for the latest month and for the year to date for the division and for each LAC unit

12. F-16 Production Unit Indicators - These eight indicators are the same as the ones used to report F-4 production unit performance Refer to the F-4 case (Figure IV-46) for definitions.

Figure IV-62. LAO Management Review Criteria

1. Training/Certification - Summary of number of employees trained and type of training received for the latest month

2. Ergonomics - Summary of efforts by the ergonomics PAT

3. LAR Sick Leave - Sick leave percentage for the latest month

4. LAR TDY - See LAO TDY definition

5. Overtime - Overtime for the avionics and structural units for the latest month and for the year to date

6. LAR Profit (Loss) - See LAO Profit (Loss) definition

7. Aircraft Avionics Status - Negotiated, required, and completed hours for the current quarter for the DRIVE program

8. Structural Repair Status - Negotiated, required, and completed hours for the structural unit's temporary (job routed) work orders

9. Structural Repair Status - Negotiated, required, and completed hours for the structural unit's MISTR workload

10. F-100 Engine Schedule - Job status of all F-16 engines in work

11. J-79 Engine Schedule - Job status of all F-4 engines in work

12. Top QDRs Received in LAR - Summary of problems and corrective actions taken on the division's most critical QDRs

13. QDRs Received - Total number of QDRs received during each month of the current fiscal year

14. Internal Customer Satisfaction Program (ICSP) - Description of purpose and benefits of this program

Figure IV-63. Topics from a Recent LAR Management Review

performance is reviewed. Criteria not included in this case, like MICAP hours, FMC rates, and AFLC 103 engineering changes requests, are examined.

At unit and subunit levels, the supervisors receive detailed production status reports like the one shown in Figure IV-64. Each of the eight blocks on this report gives the production status for a specific aircraft, as well as the dates which that particular aircraft is scheduled for each major F-16 depot maintenance process. In general, F-16 unit and subunit chiefs consider cost, quality, and delivery (schedule) to be the most important indicators of their unit performance. Overall, the aircraft directorate and its LAO and LAR divisions look most closely at product quality and profit/loss status. As for a third performance indicator, LAO tends to stress meeting delivery schedules, while LAR emphasizes producing negotiated workloads at the right cost.

System Constraints

Overview

The constraints identified by aircraft directorate managers and supervisors revolve around uncertainties about funding and workload, management information systems (MISs), personnel policies, parts availability, and training. Because the hangars at OO-ALC were built to accommodate fighter aircraft, physical space is not a constraint in accomplishing aircraft depot maintenance for F-4s and F-16s. Outmoded equipment is not a problem either. All aircraft structural repair operations will soon be moved from 13

F-16 PRODUCTION LINE PAGE: 1 AIRCRAFT STATUS			MODULE		PROD SUPV			DOCKS			IN WORK		SCHED SUPV			DATE		
			60		GRANEY			10			17		HELGON			8 JUN 71		
POS/HOUR	S/N MDS CUM/JUN	ON LINE SCHED ACT	ON LINE WORK DAYS	INC STAT	STATUS +	STATUS −	STRIP & B/M	HRI	HR I.O.	STA 53/54 DUE	ECU	BLD UP POWER	UPS	CLOSE OUT & HRT	OFF LINE	RFP		
5	01-0711 A ADF(15)	15MAY					C/W	C/W	C/W	C/W	C/W	12JUL	19JUL	21JUL	22JUL	13AUG		
[illegible]	162C/134	17MAY	47	+2		U/S	REMARKS: DCU - BB - PNT											
6 [illegible]	00-0515 A DCU(10)	12JUN					20JUN	C/W	11JUL	8JUL	12JUL	22JUL	26JUL	31JUL	1AUG	20AUG		
[illegible]	162C/147	17JUN	36	−3		U/O	REMARKS: BD - THRU - LEF - PNT : INTAKE NEEDS PAINTED											
7	78-0522 A DCU(10)	20MAY					C/W	C/W	C/W	C/W	C/W	C/W	C/W	C/W	10JUL	29JUL		
[illegible]	162C/116	17MAY	36	+5		10	REMARKS: BD - LEF - PNT 477 BLKHD CRK											
8	01-0737 A ADF(15)	17JUN					3JUL	C/W	27JUL	26JUL	31JUL	9AUG	16AUG	20AUG	21AUG	13SEP		
[illegible]	162C/154	21JUN	47	−4		−4	REMARKS: DCU - BB - PNT · INTAKE NEEDS PAINTED											
9	85-0535 B DCU(15)	4FEB					25MAR	C/W	6MAY	2MAY	7MAY	13MAY	20MAY	11JUN	12JUN	1JUL		
[illegible]	166C/260	21FEB	91	+2		−60	REMARKS: NO [illegible] BEHIND/DE 60 DAY EXT. PEND.											
10	82-0935 A ADF(15)	12APR					C/W	C/W	C/W	C/W	C/W	C/W	C/W	C/W	17JUN	12JUL		
[illegible]	162C/119	25APR	48	−15		−20	REMARKS: DCU - BB - PNT											
11	82-0724 A ADF(15)	26JUN					17JUL	15JUL	5AUG	2AUG	7AUG	15AUG	23AUG	27AUG	30AUG	24SEP		
[illegible]	162C/104	3JUL	47	−7		−7	REMARKS: DCU - BB - LEF - PNT , INTAKE NEEDS PAINTED											
12	79-0410 B DCU(10)	6JUN					13JUN	C/W	8JUL	5JUL	10JUL	18JUL	23JUL	26JUL	26JUL	14AUG		
[illegible]	166C/277	[illegible]JUN	36	+1		U/G	REMARKS: BB - LEF - PNT											

Figure IV-64. One Page of the F-16 Daily Aircraft Status Report

substandard buildings into the new ISROMS (integrated structural repair and overhaul of maintenance systems) facility. Among this facility's features are automated storage and delivery systems and paint stripping equipment.

Likewise, behavioral constraints concerning efficiency mindsets or reluctance to cross train do not appear to be as prevalent in LA as in some other AFLC organizations. Hence, this case will discuss only managerial and logistical constraints.

Managerial Constraints

The LAO and LAR division chiefs each listed archaic personnel policies as their second most critical problem. For instance, the AFLC policy on the ratio of direct to indirect labor, coupled with the loss of many schedulers and materiel controllers, has made it necessary for production workers to perform more scheduling and materiel support tasks. Also, due to the lack of flexibility in job classification rules, management is unable to shift personnel in response to workload changes. For example, even though LA has too many F-4 aircraft general and engine mechanics, the directorate is unable to make them aircraft painters because such a job transfer is considered an adverse action under OPM rules. Employees cannot be moved between units (branches) without having to be formally reclassified into a different job skill. To circumvent these policies, LAR is rewriting job descriptions and trying to get workers qualified in two or three skills.

Increased emphasis on retraining and cross training is essential if AFLC is to successfully cope with manpower reductions and business competition. Retraining personnel was considered to be the second most critical problem by the aircraft director and the LAR aircraft avionics unit chief. LA must retrain hundreds of F-4 mechanics on the F-16 and C-130 aircraft. Because the avionics unit lost a number of their junior employees through the recent RIFs, many of its senior personnel are now having to be retrained on the newer electronics technologies which the junior employees formerly handled.

Having a workforce in continual training must obviously be considered in planning and scheduling workloads. However, DOD force structure and AFLC funding changes have an even greater impact on planning. Funding tends to drive workload negotiations, especially in the repair of exchangeables. Unfortunately, the repair dollars available constantly change and may not be known with certainty until just prior to the beginning of a quarter. In addition, F-16 managers are concerned whether enough money will be available in the future for the structural modifications that will be required to maintain an aging F-16 fleet. With a $2 billion cap on all Air Force aircraft modifications, obtaining the funding for these modifications might be a problem. Finally, outside events like Desert Storm also affect depot maintenance. Of 220 F-16s scheduled for depot repair in FY 1991, tail numbers changed on 100 inputs.

Because different blocks of F-16 aircraft receive different modifications, tail number changes create havoc in F-16 planning and scheduling.

Logistical Constraints

Planning, material support, and financial management functions could be more easily accomplished if all information could be obtained from a single, real-time management information system. Ineffective, outdated, and cumbersome MISs were regarded as the most important constraint by the LAO division chief and as the second most critical problem by the F-16 production unit chief. The depot maintenance data systems do not provide information on material and labor costs down to the first-line supervisor level. Additionally, the AFLC financial system is geared toward ALCs gradually becoming proficient on a work package and starting to make a profit after four or five years. The F-16 workload, with its large numbers of short-term modifications, is the most dynamic aircraft workload in AFLC and one for which it is quite difficult to show a profit.

Although obtaining timely profit/loss information from the present data systems is impossible, as the LAO division chief pointed out, these same systems measure trivial areas of performance, like sick leave and efficiency, in the most minute detail. The aircraft operations chief believes that AFLC needs one performance measurement system for performance measurement only and one MIS capable of providing information in many areas, such as AMREP

scheduling, budgeting, and quality defects tracking. He explained how current management indicators are manipulated by the ALCs. For example, under the present QDR system, minor quality defects are neither tracked nor reported. Also, AMREP due dates are seldom missed because ALCs write off delivery date slippages as not being chargeable to their depot. Unless the command clearly specifies "freebies" and "chargeables", emphasizes trend tracking, and is able to change the mindset which says that bad news should not be reported, criteria will continue to be manipulated, no matter what performance measurement system is implemented.

Outdated guidance and transferring data systems to different host computers have resulted in extra work for F-16 planners. A year ago the operating procedures for the G037E/F aircraft planning, scheduling, and historical tracking systems changed significantly when these systems were moved from CYBER computers to the AMDAHL network. Unfortunately, the instruction manuals for these systems have not been updated since 1979. AFLC headquarters personnel claim that they are too busy developing DMMIS to take the time to update these manuals. Because of continual breakdowns in the new computer system, planners are not receiving production counts automatically and are being forced to reenter data several times and produce documents manually.

Parts availability and RTOK (retest OK) problems with avionics components were the other major problems noted by

F-16 supervisors. The F-16 production unit chief and the LAR engine unit chief noted that nonavailability of component parts was their biggest obstacle in meeting aircraft and engine delivery schedules. According to the F-16 production unit chief, sufficient spare F-16 parts were never procured. Lack of sufficient spare circuit cards is one of the factors causing excessive downtime for the avionics unit's F-16 C and D test stations. The majority of the unit's RTOK problems center around these test stations and are caused by mishandling of circuit cards. Many of these cards have mechanical relays. Consequently, when the cards are jarred in shipment, they fail. RTOK refers to LRUs and SRUs that have failed in the field but repeatedly test good on depot test stations. One software engineer works RTOK problems on a full-time basis. Obviously, resolution of these problems requires excessive additional manhours and test equipment time. Correcting software deficiencies and voids in test programs, the two most critical problems in F-16 avionics repair, will do much to eliminated RTOK problems. A bar coding system might also prove useful for tracking problem LRUs and SRUs.

F-111 Depot Maintenance

Sacramento ALC, California

Sacramento ALC Overview

The goal of the Sacramento ALC (SM-ALC) at McClellan California, is to provide superior customer support, be competitive, and be a team dedicated to continuous

improvement. The center has designed five objectives for achieving that goal. In turn, each objective contains between five and eight strategies, or subobjectives, which further define how and when that objective is to be accomplished. Figure IV-65 lists the five objectives and a few of the key strategies that have been developed for each one.

The organizational chart for SM-ALC is very similar to the one for OO-ALC (refer to Figure IV-37). Like OO-ALC, SM-ALC has four product directorates - Technology and Industrial Support (TI), Commodities (LI), Aircraft Management (LA), and, in place of ICBM, Space and C3 (Communications, Command, and Control) Management. The Commodities Directorate (LI) repairs avionics and hydraulic components and electrical accessories and ground support equipment for all USAF aircraft. The Aircraft Management Directorate (LA) performs depot maintenance on F-111s, A-10s, F-15s, KC-135s, and A-7s and has system program management responsibility for F-111, A-10, and A-7 aircraft. In addition, LA is the home of the F-22/ATF (advanced tactical fighter) system program manager (SPM) and is developing organic capability for F-117 depot repair.

Case Organization

Even though LA and LI support depot maintenance on both the F-111 and A-10 aircraft, this case will focus primarily on the aircraft directorate, LI's pneudraulics division, and TI's non-destructive inspection (NDI) division. The A-10

OBJECTIVE 1: Establish targets and implement continuous improvement strategies that significantly reduce defect rates and cycle times over the next five years.

Strategy 1-3: Develop and baseline defect and cycle time measures for major processes by 1 Jan 1992.

Strategy 1-8: Benchmark major processes by 1 October 1995.

OBJECTIVE 2: Increase business base by 5% by 1 January 1995.

Strategy 2-1: Develop center business plan by 1 December 1991 and include a business development annex by 1 October 1992.

OBJECTIVE 3: Reduce cost of logistics support by an average of 5% a year for the next five years, with a cumulative reduction of 25% by 1 October 1996.

Strategy 3-2: Identify cost drivers based on process analysis and develop process specific unit cost targets by 31 March 1992.

Strategy 3-3: Develop real time, on line financial management system useful to all levels at the center by 1 January 1993.

OBJECTIVE 4: Develop process and mechanisms to meet work force training needs by 1 January 1994.

Strategy 4-1: Complete development of occupational templates for all skills by 1 June 1992.

OBJECTIVE 5: Create self-managed team environment by 1 January 1996.

Strategy 5-1: Define roles, characteristics, responsibility, and accountability of self-managed teams by 1 December 1991.

Figure IV-65. SM-ALC Objectives and Subobjectives

case will provide an overview of the LI and TI directorates and their respective avionics and manufacturing and services divisions. For the competitive edge rankings and the questions on rating the congruency of AFLC goals and depot objectives and of performance criteria and depot objectives, the LA, LI, and TI directorate-level responses, as well as those of LA's quality branch and aircraft production (LAB) and program control divisions, are included in both cases. The F-111 case contains the responses of LAB's F-111 production and services branches, as well as those of the LI pneudraulics division (LIH) and TI's NDI division (TIN). The survey results from LAB's A-10 production and avionics branches, LI's avionics division (LIA), and TI's manufacturing and services division (TIM) are part of the A-10 case.

Aircraft Directorate and Production Division Overview

Organization

The aircraft directorate employs 2400 personnel and is divided into six divisions - aircraft production, program control, a flight test squadron, and three system program management divisions. A contracting division is matrixed to the directorate. The chart in Figure IV-66 outlines LA's divisions and branches. The majority of the directorate's 1800 direct laborers work an eight-hour day or swing shift, Monday through Friday. Three shifts are employed at the bottleneck facilities of paint, bead blasting, fuels, and the wash rack. With the reorganization, job routed repair

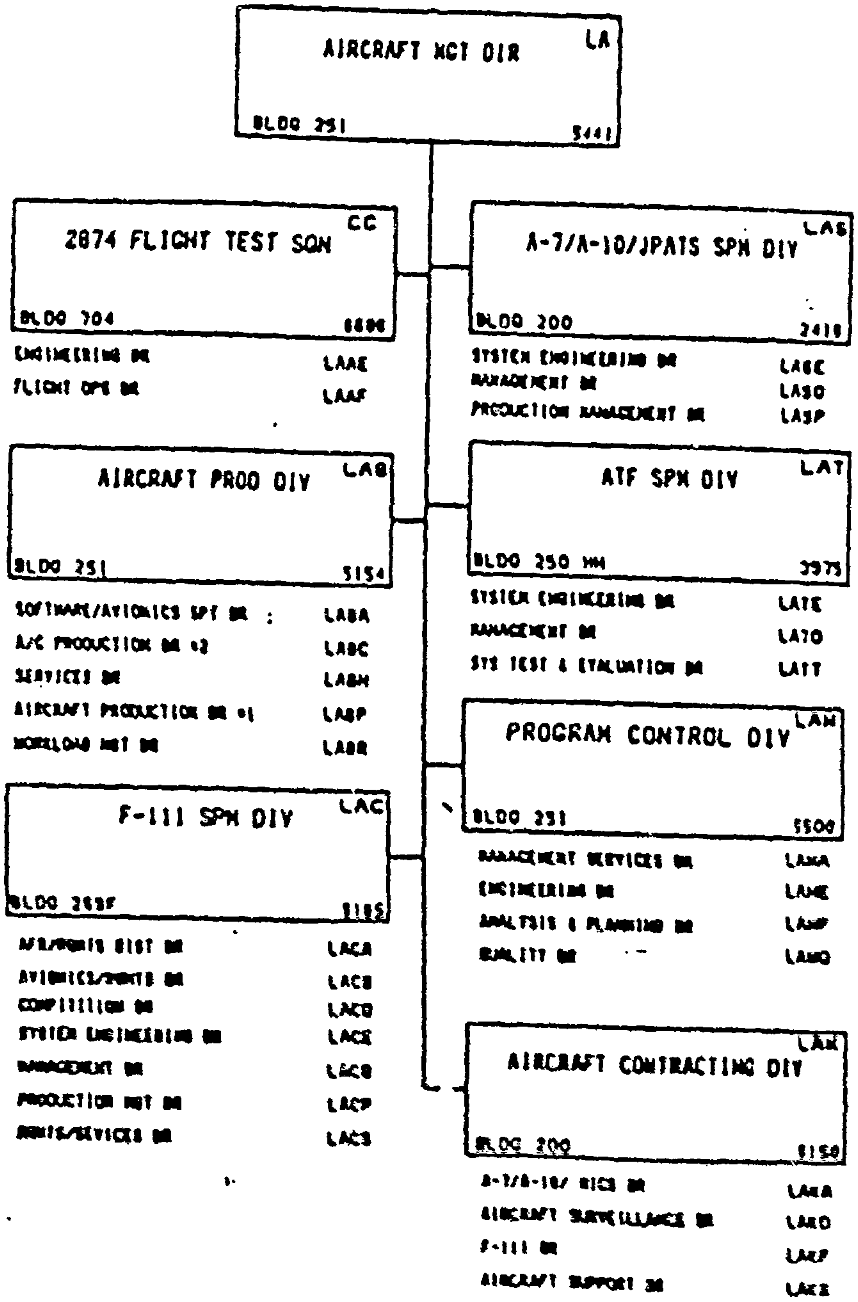


Figure IV-66. SM-ALC Aircraft Directorate Organizational Chart

of items endemic to PDM and critical to aircraft flow was assumed by LA. For instance, LA does the sheet metal work on all flaps, wings, and cowlings and also handles MISTR and job routed repairs for A-10 and F-111 avionics LRUs. Rather than being located in a separate division of LA, as is the case at OO-ALC, the LA shops that support the PDM and modification lines are part of the aircraft production division (LAB).

With 1536 employees, LAB is the aircraft directorate's largest division. The division has two aircraft production branches and software/avionics support, services, and workload management branches. Production branch #1 is responsible for depot maintenance on the F-111 and F-15 aircraft and has 660 personnel, 90 percent of which are direct labor. The F-111 section is authorized 540 people but has only 480. This section, like the F-15, A-10, and KC-135 sections, has its own schedulers, planners, and flight prep personnel. Virtually all depot maintenance for F-111s is scheduled maintenance that is driven by the aircraft structural integrity program and by modification schedules. Scheduling flexibility is further limited by the pyro grounding due dates for these aircraft. To prevent an F-111 from being out of service more often than necessary, pyro changeout is normally scheduled in conjunction with PDM.

Besides handling the paint, bead blast, fuels, and aircraft cleaning operations, the services branch repairs

parachutes and seats, runs F-111 engines across the test cell, and manufactures tubing. The branch also has a machine shop and two sheet metal shops that do MISTR repair and support the PDM and modification lines with work on canopies, F-111 spikes, and A-10 inlets. The workload management branch uses the workload packages which it draws up with the various commands to formulate annual depot maintenance schedules for each weapon system. These schedules are combined into master schedules for the various LAB sections and shops. Analysts review the master schedules to identify conflicts that may arise two to three months in the future. Two or three times a week, notices concerning these conflicts, with suggestions for their resolution, are sent to LAB branch chiefs. Figure IV-67 depicts part of a two-week master schedule for the paint shop.

Workload and Goals

Instead of having two or three large, stable aircraft workloads, SM-ALC has four smaller workloads that will change markedly in scope and quantity over the next few years. To replace the declining F-111 and A-10 workloads, LA will be doing more F-15 and KC-135 depot maintenance. The F-15 workload is doubling from 12 aircraft in FY 1991 to 24 aircraft in FY 1992. Likewise, the number of KC-135s scheduled for depot maintenance at SM-ALC is increasing from five inputs in FY 1991 to 18 and 44 aircraft in FY 1992 and FY 1993, respectively. A-10 work will decline dramatically

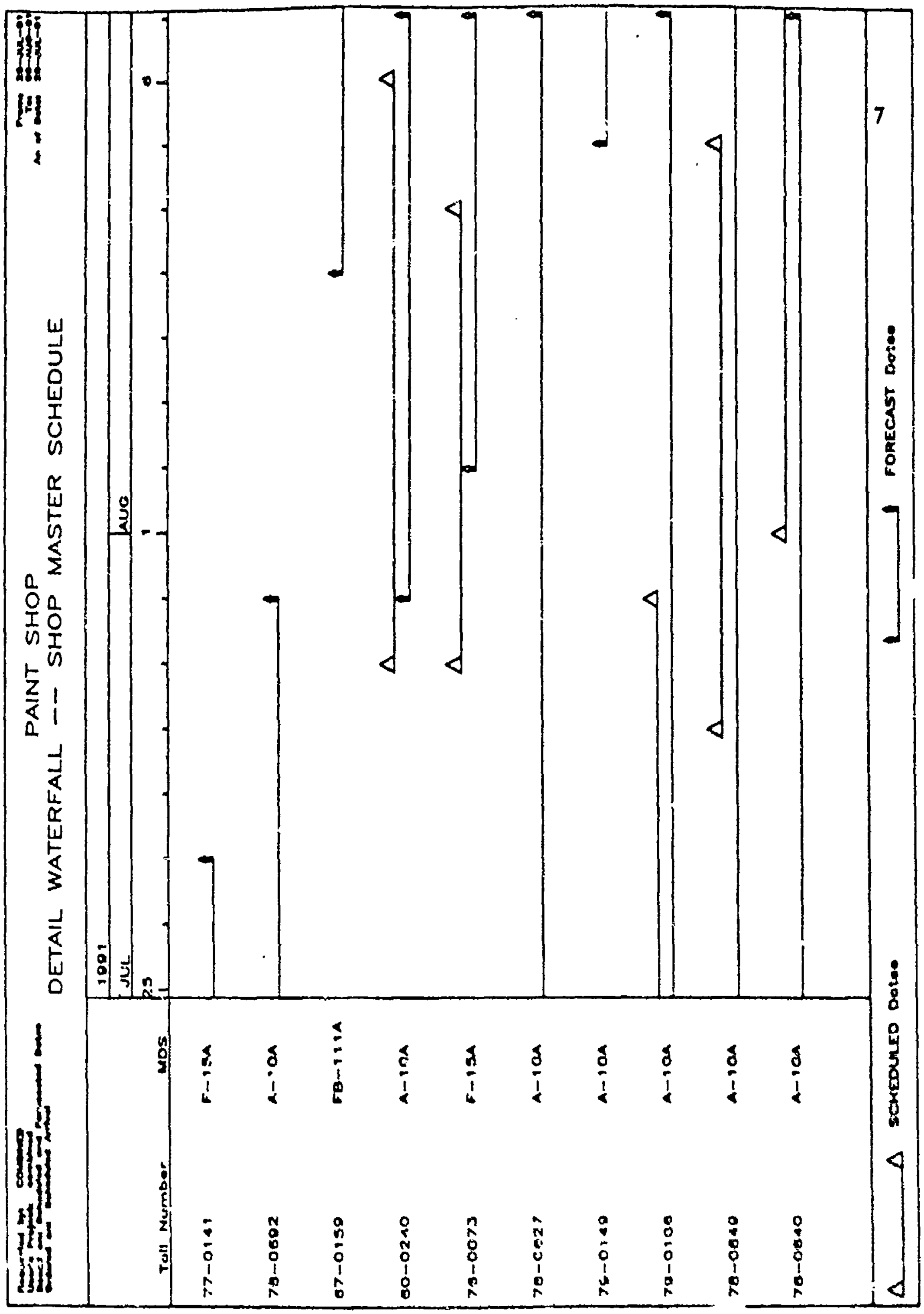


Figure IV-67. Master Schedule for the SM-ALC Aircraft Paint Shop

after the first quarter of FY 1993, and by the end of FY 1994, the F-111 workload will be half of what it is today.

Due to force structure changes, the number of F-111s in the USAF fleet is being reduced from 370 to 150 aircraft. As a result, during FY 1992 LA will be required to perform depot maintenance on only four MDSs (mission design series), or models, of F-111s, rather than on seven or eight MDSs, as in the past. Included in the four MDSs are the one or two Australian C model F-111s that are sent to SM-ALC each year for coldproofing and resealing. The other three models of F-111s are assigned to two bases in the United Kingdom and to units at Mt. Home AFB, Idaho, and Cannon AFB, New Mexico. Over the next two years, the F-111 SPM will install two digital flight control (DFC) modifications on the F-111s remaining in the fleet. Consequently, SM-ALC's F-111 workload will actually increase in FY 1993. In FY 1991, 56 F-111 aircraft, averaging 164 flow days, were scheduled to receive PDM and/or modifications at SM-ALC. However, in support of Desert Storm, depot maintenance on six F-111Fs was accelerated by 74, 80, 107, 108, 120, and 129 days. Figure IV-68 illustrates F-111 PDM flow.

LA's primary goals are to guarantee customer satisfaction, create a positive work environment, and establish accountability at all levels. Objectives have been developed for each goal and are outlined in Figure IV-69. To ensure the accomplishment of these goals and

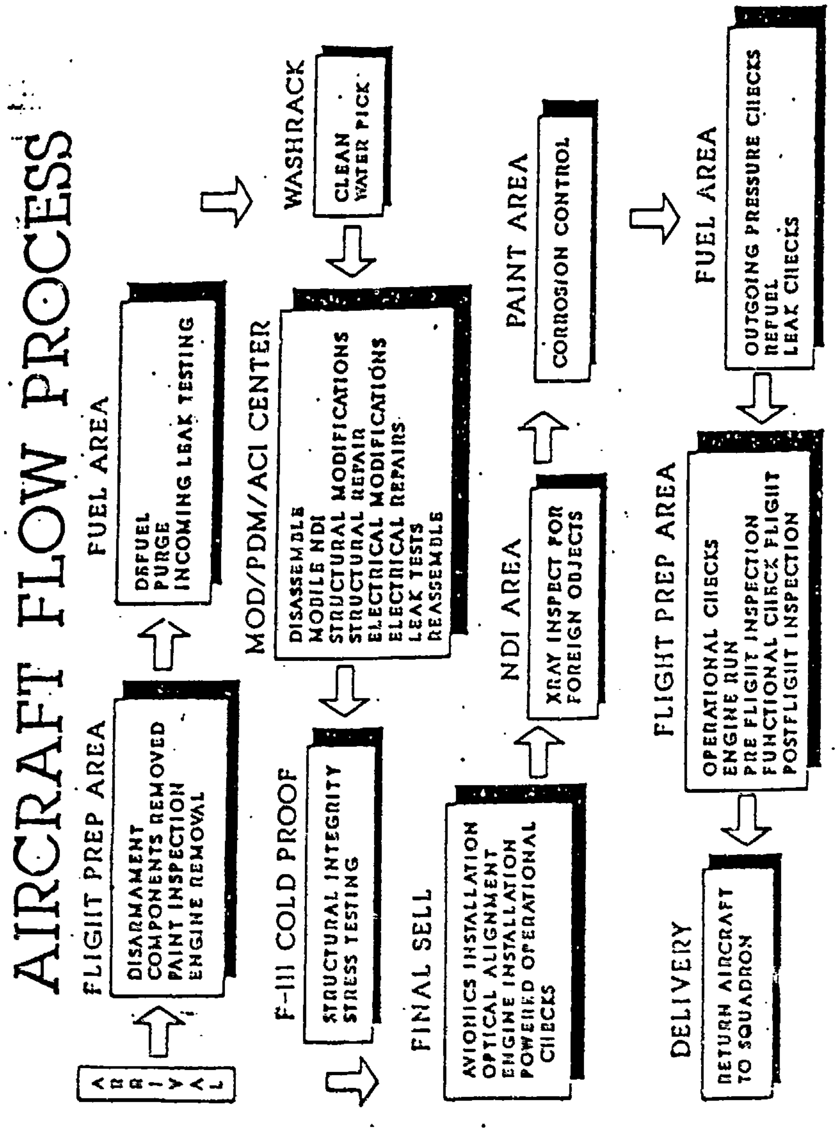


Figure IV-68. F-111 PDM Flow

GOAL 1: Guarantee customer satisfaction

Objective 1: Define customer satisfaction indicators
Objective 2: Baseline customer satisfaction indicators
Objective 3: Make indicators and timely feedback available
Objective 4: Realize year-to-year improvement in performance
Objective 5: Be a competitive and thriving business

GOAL 2: Create a positive work environment

Objective 1: Establish a directorate awards policy/ program
Objective 2: Charter a personnel and appraisal working group
Objective 3: Establish a directorate policy on communication
Objective 4: Have a plan to seek out perceived obstacles and find ways to change our work environment
Objective 5: Be a good neighbor (includes waste management)
Objective 6: Establish a directorate orientation program
Objective 7: Establish a long range facility plan

GOAL 3: Establish accountability at all levels

Objective 1: Participants understand and accept responsibility to do their jobs & improve processes professionally
Objective 2: Authority to carry out the job resides at the lowest appropriate level
Objective 3: Effective acquisition and utilization of resources are a measure of accountability
Objective 4: Participants perform mission related work
Objective 5: Performance recognition is linked to accountability for job accomplishment and process improvement

Figure IV-69. Aircraft Directorate Goals and Objectives

objectives, detailed subobjectives and subobjective milestone schedules have been established for each objective. An example of two objectives and several subobjectives for the first goal is given in Figure IV-70.

For each LA goal, the aircraft production division has outlined some areas on which it plans to focus. Under customer satisfaction, LAB plans to concentrate on meeting production commitments (delivering a quality aircraft at the right cost by the AMREP due date), improving customer relations, and providing a safe work environment. Creating a positive work environment in LAB includes improving communication, removing obstacles to organizational improvement, and creating a master facility plan. For LAB, establishing accountability involves empowering the workforce and focusing on and rewarding process improvement. The LAB division chief believes that the division's primary goal is customer satisfaction and that all other goals and objectives should support that goal.

Overview of TI's Non-destructive Inspection Division

The goal of the non-destructive inspection (NDI) division (TIN) is to attract workloads to SM-ALC by exploiting the division's unique capabilities. To accomplish this goal, TIN plans to establish a marketing strategy and a technical, effective representation of all TIN processes. By utilizing the technology transfer act, the division hopes to expand its customer list to include commercial and foreign aircraft, the DOD space workload,

DESCRIPTION	OPR	SUBOBJ START	SUBOBJ FINISH	DUR
OBJECTIVE 4: REALIZE YEAR-TO-YEAR IMPROVEMENT IN PERFORMANCE AGAINST CUSTOMER DEFINED INDICATORS OF SATISFACTI				
SPECIFICALLY LINK PROCESS RESPONSIBILITY TO PARTICULAR INDICATOR DATA	ALL	1-APR-91	16-AUG-91	98
IDENTIFY INTERDEPENDENCIES OF PROCESSES	ALL	1-APR-91	16-AUG-91	98
ESTABLISH PROCESS PRIORITIES BASED UPON PRIORITY OF INDICATORS & INTERDEPENDENCY FACTORS	ALL	1-APR-91	1-OCT-91	129
CONTINUE PROCESS IMPROVEMENT METHODOLOGY & CONFIRM PRIORITY OF IMPROVEMENTS	ALL	1-APR-91	1-NOV-91	151
OBJECTIVE 5: BE A COMPETITIVE AND THRIVING BUSINESS				
ADOPT THEORY OF CONSTRAINTS (THROUGHPUT) MODEL	ALL	1-APR-91	1-AUG-91	87
ESTABLISH A WAY TO MEASURE REWORK, DELAYS, WORK AROUNDS, ETC. TO FOCUS PROCESS IMPROVEMENT	ALL	1-APR-91	1-AUG-91	87
ESTABLISH A BUSINESS OFFICE TO SEEK WORKLOAD FROM ALL SOURCES	LAWALL	1-APR-91	30-AUG-91	108
BASELINE OUR INDUSTRIAL CAPABILITY & EXTRACT A LOGICAL NICHE ON WHICH TO BUILD OUR BUSINESS PLAN	LABLAW	1-APR-91	1-OCT-91	129
ESTABLISH A TEAM TO SEEK & IMPORT TECHNOLOGIES VITAL TO SUPPORT OF OUR BUSINESS PLAN	LAWALL	1-APR-91	1-OCT-91	129
REDUCE COST OF PRODUCING AIRCRAFT BY 3%	LAB	1-APR-91	1-OCT-91	129
REDUCE CUSTOMER FOUND WORKMAN DEFECTS BY 5%	ALL	1-APR-91	1-OCT-91	129
DESIGNATE PRIORITY WORKLOADS AND PROCESSES FOR RESOURCE SUPPORT	ALL	1-APR-91	1-OCT-91	129
REDUCE FLOWDAYS OF AIRCRAFT BY _____%	LAB	1-APR-91	1-OCT-91	129
ESTABLISH WAYS TO ADD SKILL VERSATILITY	ALL	1-APR-91	1-OCT-91	129
DEVELOP STRATEGY TO SEEK TANGIBLE BENEFITS FOR EMPLOYEES WHO DRIVE COSTS DOWN AND/OR INCREASE QUALITY THROUGHPUT	ALL	1-APR-91	1-NOV-91	151
UNDERSTAND THE NEW STOCK FUND SYSTEM	LAW	1-APR-91	2-DEC-91	170

1991 1992
A M J J A S O N D J F M A M J

Figure IV-70. LA Subobjectives for Customer Satisfaction Goal

artillery, and marine components. With its neutron radiography (N-ray) technology, TI's NDI facility is the only facility in the world capable of detecting minute amounts of moisture and corrosion in large component aircraft parts. Although the N-ray technology has proven useful for detecting corrosion in F-111 aircraft, it has proven even more effective for detecting moisture in F-15 aircraft parts and will be vital for performing NDI tasks on the F-117 and F-22 aircraft in the future. For the first ten aircraft on which N-ray was employed, 268 incidents of moisture were found. By contrast, X-ray detected only 63 incidents of moisture on these same ten airplanes. As a result of having this new technology, TIN's F-15 and F-111 workload has recently increased by 75 percent.

The NDI division has three branches - health physics, nuclear operations, and NDI support. The latter branch has 68 people and is the one that directly supports LA's PDM and modification lines. It is divided into four sections - magnetic particle/rubber and liquid penetrant, ultrasonics and eddy current, X-radiography, and neutron radiography. Training for NDI employees is long and intensive. It generally takes 18 months to become certified as an X-ray technician and two years to be fully qualified in N-ray technology. The division is considering merging the X-ray and N-ray job skills in order to have more flexibility in moving people to various workloads. Unfortunately, because NDI job skills are very marketable outside DOD, the more

training TIN gives its personnel, the more likely it is to lose some of them to the private sector.

Overview of LI's Pneudraulics Division

The commodities directorate's pneudraulics division (LIH) consists of a management support branch and the pumps and miscellaneous components and servo flight control product teams (branches). Because 70 percent of the items that the division repairs are managed by OC-ALC and another 20 percent are managed by OO-ALC, LIH's product teams do not include such individuals as item managers and equipment specialists. The majority of the division's 386 personnel work a day shift, but, due to an insufficient number of test stands, a considerable amount of testing is done on night shift. The directorate and the division have recently adopted an alternate work schedule which has two 12-hour timeframes (shifts), Monday through Friday. Employees were allowed to choose their own schedule and work either an eight-, nine-, or ten-hour shift four or five days a week. The only schedule restriction imposed by management was that at least 50 percent of the workforce be present on Mondays and Fridays.

Scheduled maintenance represents 90 percent of the LIH workload and 95 percent of the servo flight control branch's work. This branch has recently implemented a manual, serial number tracking system and is also taking steps to reduce paperwork and material costs. For example, on items that fail final test, rather than being required to reaccomplish

the same work control documents several times, mechanics may now reuse the original document for up to seven failures. In addition, instead of automatically replacing all failed components with new ones, a PAT is trying to determine which components on various end items can be refurbished and reused without compromising product quality. For some time the branch has been repairing, instead of buying, spools and sleeves.

F-111 servo flight controls account for sixty percent of the servo flight control branch's workload. Until recently the F-111 servo damper, which provides the interface between the electrical and hydraulic systems on the F-111 aircraft, had a 50 percent rework rate. An aerospace engineer worked closely with shop floor technicians and discovered that pronounced spiral grooves on the inside of the servo damper's nozzles created disturbances in the spray patterns of hydraulic fluid used to null a paddle. Because engineering drawings did not contain specifications for the inside finish of the nozzles, nozzle spray patterns varied considerably and were a major factor in causing F-111 servo dampers to fail final test. By procuring nozzles with polished internal bores and lapping existing nozzles in-house, LIH has seen the F-111 servo damper rework rate decline to 20 percent.

Competitive Edges

On the basis of criteria, the competitive edge rankings for the LA, LI, and TI directors were very similar. All

three directors considered cost, delivery, and quality to be the three most important competitive edges and ranked cost as the most critical edge. In the objectives category, the LI and TI directors also regarded quality, cost, and delivery to be the most important edges. In this category, though, the aircraft associate director ranked quality, flexibility, and innovation as the most critical edges. She believed that these three elements were essential if aircraft were to be delivered to customers on time and at the least cost. Considering the nature of LA's workload, it would seem that flexibility and innovation must be emphasized for the directorate to compete and survive.

On the other hand, the division rankings display little agreement either on the basis of objectives or criteria. By criteria, three of the four division chiefs ranked cost as the most critical competitive edge. Flexibility and innovation tended to be ranked as the least important edges. By objectives, these two elements were regarded as unimportant by the TI and LI division chiefs but were considered to be somewhat critical (ranked third and fourth) by the aircraft production chief. In the objectives category, all division chiefs, except the NDI chief, ranked quality as the most critical competitive edge. The directorate and division rankings are displayed in Figures IV-71 and IV-72.

As is evident from Figure IV-73, on the basis of criteria, the rank order for the competitive edge rankings

Aircraft Directorate (n=1)		
Rank Order	By Objectives	By Criteria
1	Quality	Cost
2	Flexibility	Delivery
3	Innovation	Quality
4	Cost	Innovation
5	Delivery	Flexibility
6	Lead Time	Lead Time

Commodities Directorate (n=1)		
Rank Order	By Objectives	By Criteria
1	Quality	Cost
2	Delivery	Delivery
3	Cost	Quality
4	Flexibility	Lead Time
5	Innovation	Flexibility
6	Lead Time	Innovation

TI Directorate (n=1)		
Rank Order	By Objectives	By Criteria
1	Quality	Cost
2	Delivery	Quality
3	Cost	Delivery
4	Lead Time	Innovation
5	Flexibility	Flexibility
6	Innovation	Lead Time

Figure IV-71. Directorate Competitive Edge Rankings

Rank Order	LA Aircraft Production		LA Program Control	
	By Objectives	By Criteria	By Objectives	By Criteria
1	Quality	Cost	Quality	Cost
2	Delivery	Quality	Cost	Delivery
3	Innovation	Delivery	Delivery	Quality
4	Flexibility	Lead Time	Innovation	Innovation
5	Cost	Flexibility	Flexibility	Flexibility
6	Lead Time	Innovation	Lead Time	Lead Time

Rank Order	TI Non-Destructive Inspection		LI Pneudraulics	
	By Objectives	By Criteria	By Objectives	By Criteria
1	Cost	Cost	Quality	Quality
2	Lead Time	Delivery	Cost	Cost
3	Delivery	Lead Time	Lead Time	Lead Time
4	Quality	Quality	Delivery	Delivery
5	Flexibility	Flexibility	Flexibility	Flexibility
6	Innovation	Innovation	Lead Time	Lead Time

NOTE: (n=1) for each division

Figure IV-72. Division Competitive Edge Rankings

LA, LI, and TI Branch Chiefs (n=5)				
Rank Order	By Objectives	Ranking	By Criteria	Ranking
1	Quality	1.00	Quality	1.20
2	Delivery	3.60	Cost	2.40
3	Lead Time	3.60	Delivery	3.40
4	Cost	3.80	Innovation	4.00
5	Flexibility	4.40	Lead Time	4.20
6	Innovation	4.60	Flexibility	5.80

LA, LI, and TI First-Line Sueprvisors (n=4)				
Rank Order	By Objectives	Ranking	By Criteria	Ranking
1	Quality	1.00	Quality	1.00
2	Cost	2.75	Cost	2.75
3	Delivery	3.25	Delivery	3.25
4	Innovation	4.50	Innovation	4.50
5	Lead Time	4.50	Lead Time	4.50
6	Flexibility	5.00	Flexibility	5.00

Figure IV-73. Competitive Edge Rankings by Branch Chiefs and First-Line Supervisors

of branch chiefs and first-line supervisors is identical. However, by objectives, the rankings of these two groups are quite different. Both sets of supervisors ranked quality as the most critical competitive edge and regarded flexibility as being relatively unimportant. Surprisingly, first-line supervisors gave cost a higher ranking than branch chiefs. This ranking could indicate that F-111 first-line (five-digit level) supervisors, who are often the persons in charge of the lowest-level RCCs, are being seriously pressured to meet budgets and reduce costs.

Performance Criteria

SM-ALC and Aircraft Directorate Criteria

Rather than receiving a comprehensive monthly management review from each of the four major product directorates, SM-ALC's commander tends to obtain information on individual areas, such as DMIF funds status and aircraft production, in separate briefings. Included in these briefings are the A-10 and F-111 monthly weapon system reviews. The F-111 review presents aircraft readiness (FMC rates) for the entire F-111 fleet and for each command and each base. The weapon system status (i.e., status of all aircraft and engines assigned) for each base is also given. This review also looks at the status of aircraft modifications and of critical material supporting the PDM lines and contains bar graphs of F-111 customer reported defects for each of the previous twelve months.

The DMIF financial status review that is presented to the center commander looks at OPMD, direct labor efficiency, budgeted and actual earned hours, overtime, authorized and assigned manpower, and overall profit/loss for each of the four product directorates for the latest month and for the year to date. For the center, the briefing presents the cumulative targeted and actual direct product standard hours (DPSHs), a DPSH cost rate analysis (by eight expense categories), and an organic budget status. The organic budget status slide shows the budgeted and actual labor expenses, material expenses, other expenses, cost of goods sold, revenues, yield (DPAHs - direct product actual hours), and profit/loss. DMIF review concludes with an examination of oldest JONs, of II's greatest profit and greatest losses by repair group category, and of the projected and actual WIP for LA, LI, TI, and the space directorate.

Aircraft Division Criteria

Each month the aircraft directorate sends the SM-ALC command section a set of bar graphs detailing LAB performance on schedule conformance for aircraft and exchangeables, exchangeables production, direct labor utilization, and direct material utilization. Targeted and actual direct labor and material utilization (in earned and actual hours and in dollars) is given for each month of the current fiscal year. Additional charts provide budgeted versus actual direct labor efficiency percentages and direct

material utilization (in dollars per hour) for the aircraft directorate and for each of four LAB branches (services, avionics, and the two production branches). Every month the program control division's (LAW's) quality branch compiles a quality review and distributes it to the flight test squadron, LAB, and the LAB branches. This review provides detailed information on FCF flight rates, defect rates, and actual defects, by weapon system, as well as data on customer reported defects.

On an occasional basis LAW also presents the LA director and the center commander briefings on DMIF performance and on the status of LA's COD, O&M, and 583 engineering funds. These reviews also include information on overtime usage, sick leave usage, manpower strength and vacancies, work in process, FCF defects (by system and type of aircraft), and planning for future workloads (refers to the F-117 and F-22 aircraft). LAB's workload management branch (LABR) compiles information for the division's weekly aircraft production status meetings. Production status for F-111 and F-15 aircraft is reviewed on Wednesdays; the status of other aircraft (including A-10s) is briefed on Thursdays. LABR also assembles data on capacity and manning requirements on an as-needed basis. Information from a FY 1992 workload review is discussed under the system constraints section.

LI Pneudraulics Division Criteria

LI's pneudraulics division holds a monthly division standup at which production, material status, and quality data are reviewed. The quality slides summarize the number of QDRs reported, TDRs (teardown deficiency reports) investigated, and the causes of the QDRs and TDRs. An analysis of customer comment cards is also presented. The material status portion presents a profit/loss analysis for the division and its two branches and for selected end items. It also looks at MIC inventory and the number of items due out to maintenance and the number of days they have been due out. The largest part of the material status briefing reviews backorders. Information is given on total backorders, backorders by RCC, backorders with closed or erroneous JONs, the ten highest cost backorders, the ten oldest backorders, and backorder reconciliation.

The LI production review examines quarterly MISTR production, various engineering indicators, sick leave usage, and training audit results for the latest month. The number of observations, administrative findings, and product findings is reported for each audit. Sick leave is shown by hours and by percentages for each RCC in the division. The engineering slides present information on the status of temporary work orders and on the total number of suggestions received and processed, work control documents updated, engineering change requests received, and technical order change requests received for each of the previous four

months. The MISTR production slides show the number of units originally negotiated, scheduled (based on final negotiations), and produced and the percentage produced on time, for the pump and servo flight control product lines. The MISTR units are further subdivided according to the ALCs which have item management responsibility for them. The production briefing also contains slides which show the number of open and completed MICAP work orders and the status of non-programmed job orders.

System Constraints

Overview

The constraints for the aircraft production division, LI's pneudraulics division, and TI's NDI division are primarily concerned with manpower, parts availability, outdated equipment, and lack of facility space. Each of these three division chiefs, as well as LAB's services and production branch chiefs, listed manning shortfalls as their top constraint. The second most critical problem for LAB and its services branch was facility and equipment constraints, while parts availability ranked as the second leading concern for the pneudraulics division chief. Though the amount of F-111 depot maintenance will decline in the future, it is being replaced by F-15 work. And, even though the NDI division is presently faced with a decreasing workload, it anticipates that new weapon systems, like the F-117 and F-22 aircraft, and the acquisition of commercial accounts will enable it to expand its customer base. Hence,

for this case three categories of constraints - physical, managerial, and logistical - will be examined.

<u>Physical Constraints</u>

The aircraft production division's physical constraints are a direct result of the shortages it has in entry-level skills like aircraft cleaning and fuel resealing/desealing. Because LAB's bottleneck facilities (paint, bead blast, fuels, and wash rack) are not fully utilized 24 hours a day, the division technically does not have any physical constraints. However, with the hiring freeze, LAB cannot hire entry-level workers and therefore is unable to man these operations around the clock. In addition, the hangars and the paint and wash rack facilities were built to accommodate fighters, not large cargo aircraft. The increase in the KC-135 workload, coupled with the fact that during the next year both the A-10s and F-111s will be undergoing major modifications that must be performed indoors, exacerbates the existing physical problems.

The lack of space is particularly acute in FY 1992. Load profiles similar to the one in Figure IV-74 were analyzed to arrive at the required stall numbers shown in Figure IV-75. The stall requirement breakdown is extracted from a FY 1992 workload briefing developed by LAB's workload management branch. PMB refers to the plastic media blasting done by the bead blast facility. The required figures are based on a projected 1992 workload at SM-ALC of 242 total aircraft and assume an average of 30 F-111s, 43 A-10s, 10 F-

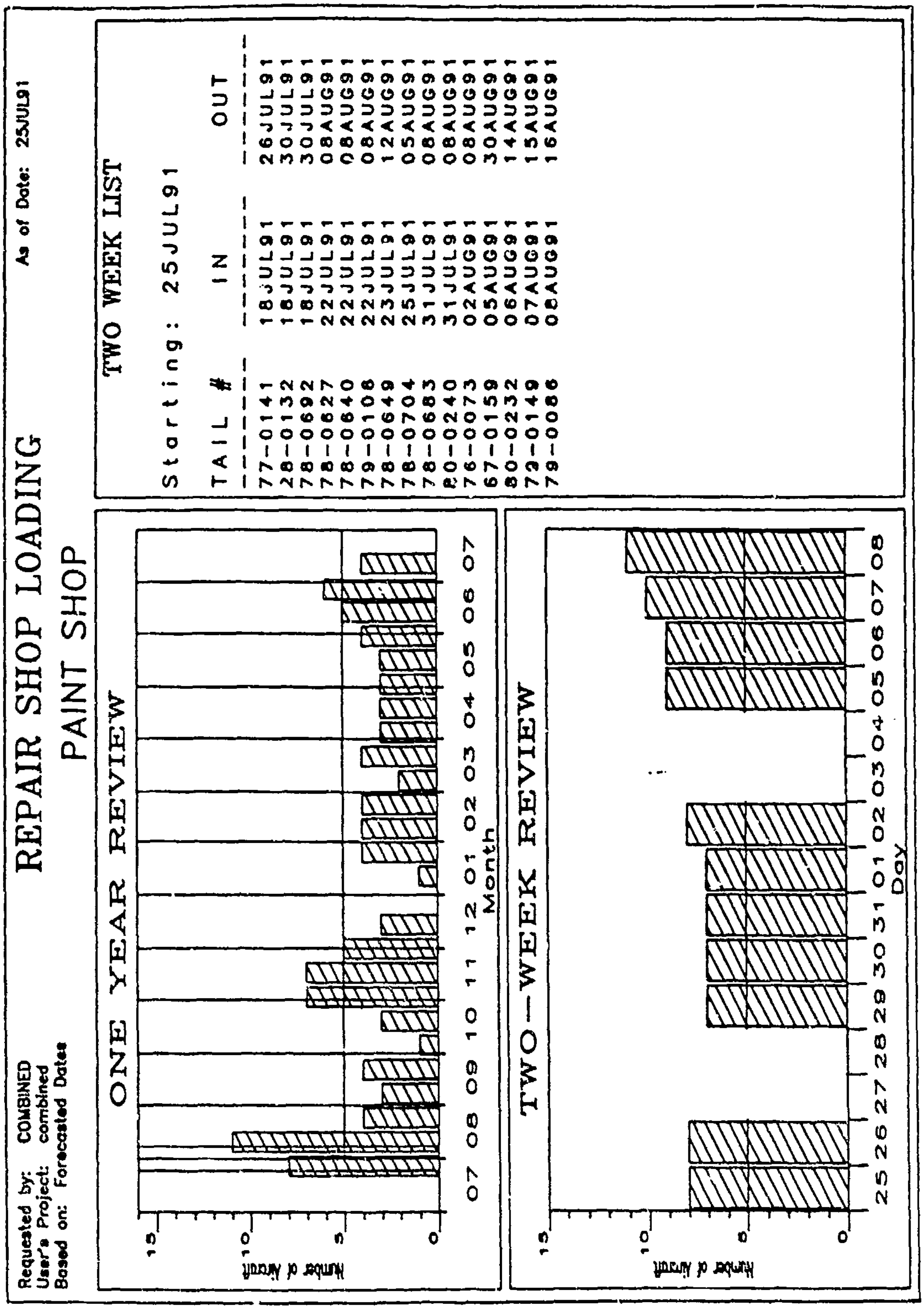
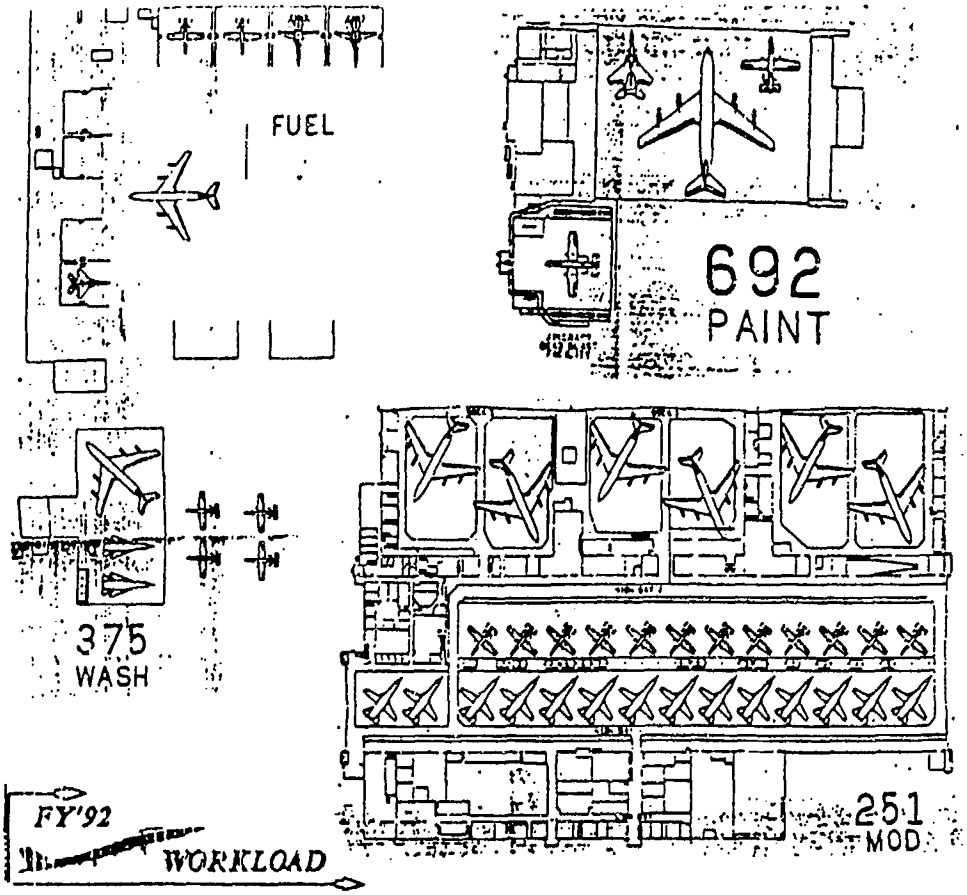


Figure IV-74. Load Profile for the SM-ALC Paint Shop



STALL REQUIREMENT BREAKDOWN

FUEL AREA

•• REQUIRED	11	
•• AVAILABLE	8	
SHORTFALL		-3

WASHRACK

•• REQUIRED	9 (PEAK REQ's 13)	
•• AVAILABLE	6 (FIGHTER SIZE)	
SHORTFALL		-3

PMB (INCLUDING PRE/POST)

•• REQUIRED	4	
•• AVAILABLE	1	
SHORTFALL		-3

PAINT

•• REQUIRED	5	
•• AVAILABLE	3	
SHORTFALL		-2

Figure IV-75. Diagram and Capacity of LA Bottleneck Facilities

15s, and 11 KC-135s on station. While an average of only six aircraft are expected to be in the wash rack at any one time, one of these aircraft will be a KC-135, which occupies four fighter stalls. The top of Figure IV-75 provides a visual picture of LAB's bottleneck areas and its primary modification hangar. However, this diagram shows only a few of LAB's production facilities and is not accurate in terms of scale or relative facility location.

To alleviate the various facility constraints, the division is initiating several process improvements and reassigning tasks of skills shortage people. For example, to assist aircraft painters, aircraft cleaners are now doing the hot glue sealing of aircraft openings. In addition, the manual resealing process for F-111 fuel tanks has recently been replaced with a quicker spray sealant process. Bead blast workers have also begun using a new type of tape that keeps out media blast and comes cleanly off an aircraft. The tape that was formerly employed left a lot of residue when it was removed. Finally, now that SM-ALC uses JP-8 aircraft fuel, LAB is investigating whether purging and depuddling fuel tanks is still necessary.

Although process improvements and task realignments can help alleviate some of LAB's physical constraints, larger facilities with up-to-date technology would be even more beneficial. Due to a lack of space, LAB must depaint KC-135s instead of bead blasting them. Depainting takes much longer and is subject to stringent environmental

regulations. Also, because of the tremendous overspray associated with painting a KC-135, no other aircraft can occupy the paint facility while these aircraft are being painted. In addition, the old pump systems in the paint barn frequently fail, causing this facility to be shut down for extended periods. Because of outdated fuel purging technology, four people, instead of two, are needed for this operation. Inadequate industrial drains at the wash rack necessitate a number of workarounds in this area. In summary, due to outmoded technology, LAB must extend process flows and use more people to perform process workarounds. Unfortunately, funding for upgrading equipment and facilities is nonexistent, so facilities like a new paint shop will probably not be available for several more years.

Managerial Constraints

Although the primary managerial constraint, the DOD hiring freeze policy, has already been mentioned, its implications for LAB, LIH, and TIN have not been discussed. In LAB the pool of entry-level workers in the aircraft cleaning and fuel sealing job skills is rapidly diminishing. For instance, though 60 fuel sealers are authorized, the division has only 18. In the past, personnel that proved themselves in the entry-level jobs were promoted to the next higher wage grade and allowed to train to become sheet metal workers, electricians, hydraulic technicians, or general aircraft mechanics. In turn, they were replaced by new hires from the private sector. With the promotions freeze,

the only path out of the entry-level jobs is the "716" program. Under AFR 40-716, civil service employees may apply for a different job if they can prove that they are physically unable to perform their present duties. To create a larger pool of entry-level workers, LAB is investigating combining the cleaning, painting, and fuels skills into a single job skill with wage grade progression between the three areas.

Likewise, to alleviate its shortage of N-ray technicians, TI's NDI division is considering combining the neutron radiography and X-radiography job skills. Fortunately, the SM-ALC commander recently lifted the hiring freeze for N-ray technicians, so shortfalls in this career field should be less acute in the future. Increased cross training on the repair of several end items might also help LI's pneudraulics division resolve some of its manpower problems. To handle its current workload, the division needs 100 more people. The FY 1991 workload increase is a result of Desert Storm and amounts to approximately 500,000 manhours, or an additional quarter's worth of work. While the employees in LIH possess a common skill, the skills shortages in LAB cross several career specialties. With the hiring and promotions freezes, no new journeymen are being trained in the sheet metal and electrical career fields. Consequently, there is a shortage of sheet metal workers and electricians, especially for F-111 depot maintenance. The two F-111 DFC modifications occurring simultaneously in FY

1992 and FY 1993 will be a further drain on the #1 production branch's highly skilled sheet metal and electrical technicians. Finally, due to the doubling of the F-15 workload, a number of F-111 mechanics will soon have to be transferred to the F-15 section.

A number of SM-ALC's workload fluctuations stem from AFLC policy and recent AFLC workload reassignments, like the transfer of additional F-15 work to SM-ALC. Because LA is responsible for depot maintenance on twelve different MDSs of aircraft, the directorate is taxed with supporting a multiplicity of work schedules, work documents, tooling, and equipment. Hence, it is not surprising that workload fluctuations and inconsistencies were considered to be one of the most critical problems by the aircraft director, the workload management branch chief, and the F-111 section chief. The latter two individuals noted that F-111 modification decisions frequently changed, making changes in work packages and schedules unavoidable. The LABR branch chief pointed out that the F-111 workload requires about a dozen different work packages. Fortunately, with the branch's computerized scheduling system, long-term planning and short-term scheduling alterations can be more easily accomplished than in the past.

Logistical Constraints

Prior to the hiring freeze, parts availability was the most critical problem for LIH and LAB's production branches and F-111 section. While parts problems in LAB are the

result of items not being available when needed for aircraft reassembly, delays in routing components through various backshops cause many of LIH's material support problems. Because TI's plating, grinding, paint, and blasting shops service the whole base, they tend to be inundated with work during the first 45 days of a quarter. LIH recently obtained permission from TI to move some items into TI backshops early (30 days prior to the start of a quarter). Unfortunately, due to AFLC policy, the only end items for which parts can be ordered prior to the beginning of a quarter are those items that are part of a carryover workload. Though TI and LI have agreed on the financial arrangements required for routing items to the backshops early, a six-month saturation of backshop work has prevented this new procedure from being implemented. Therefore, to become more self-sufficient, LIH is establishing its own cleaning, blasting, painting, and grinding capabilities.

Like the key managers in OO-ALC's aircraft directorate, the LA associate director and LAB division chief expressed considerable dissatisfaction with the depot maintenance data systems. They observed that financial profit/loss information is not available when it is needed and is not provided in the detail necessary for managing a business. However, the only manager that talked about problems with the performance measurement system was the pneudraulics division chief. The LIH chief has eliminated efficiency criteria from the performance appraisal criteria for his

supervisors and shop floor personnel. He believes that efficiency is the greatest deterrent to product and process improvement. Additionally, because efficiency is no longer a factor in LIH performance appraisals, he contends that shop floor personnel will now more readily work with management to identify hidden hours and obsolete job routings. The LIH division chief, like his LAB counterpart, evaluates his branches on due date performance and quality/ process improvement. Unfortunately, these divisions receive a lot of pressure from the center level to maintain high efficiencies. As long as OPMD and direct labor effectiveness are high priorities for the SM-ALC commander, it may be difficult for some of SM-ALC's progressive division chiefs to effect as much permanent change as they desire.

A-10 Depot Maintenance

Sacramento ALC, California

A-10 Depot Maintenance Overview

The A-10 fleet presently has 643 aircraft distributed among 19 units at the following locations: Alconbury, United Kingdom; Bentwaters, United Kingdom; Eielson AFB, AK; Osan AB, Korea; Battle Creek, MI; Davis Monthan AFB, AZ; England AFB, LA; Myrtle Beach AFB, SC; Nellis AFB, NV; Eglin AFB, FL; Barksdale AFB, LA; Richards Gebauer AFB, MO; Grissom AFB, IN; New Orleans, LA; Barnes, MA; Bradley, CT; Glen L. Martin, MD; Truax, WI; and Willow Grove, PA. Although SM-ALC is the primary depot for A-10 aircraft, a

small portion of A-10 depot maintenance is performed at overseas sites in the United Kingdom and Korea. With only two MDSs and no PDM program, A-10 depot maintenance tends to be less complicated than that of the other weapon systems examined in this study. Once the LASTE (low altitude safety and targeting enhancements) modification is completed, A-10s will only be sent to the depot for corrosion control work. The LASTE modification, which is being installed on 398 aircraft, incorporates enhanced attitude control, improved HUD (heads up display) symbology, and a ground collision avoidance system. The completion of this modification, coupled with the retirement of 150 to 200 A-10s from the active USAF fleet, will result in a significant decrease in SM-ALC's A-10 workload after December, 1992.

The A-10 aircraft section has 316 people and is part of LAB's #2 production branch. Though the content of the A-10 depot maintenance workload is fairly stable, in past years relatively high numbers of drop-in aircraft have caused some scheduling problems. With the installation of the LASTE modification, unscheduled maintenance has dropped substantially and probably accounts for no more than ten percent of the A-10 workload. During FY 1991, 131 A-10s were programmed for depot maintenance at SM-ALC. Flow days varied considerably and ranged from 58 to 138 days, depending on the amount of modification and corrosion work required. Figure IV-76 depicts the A-10 depot maintenance flow.

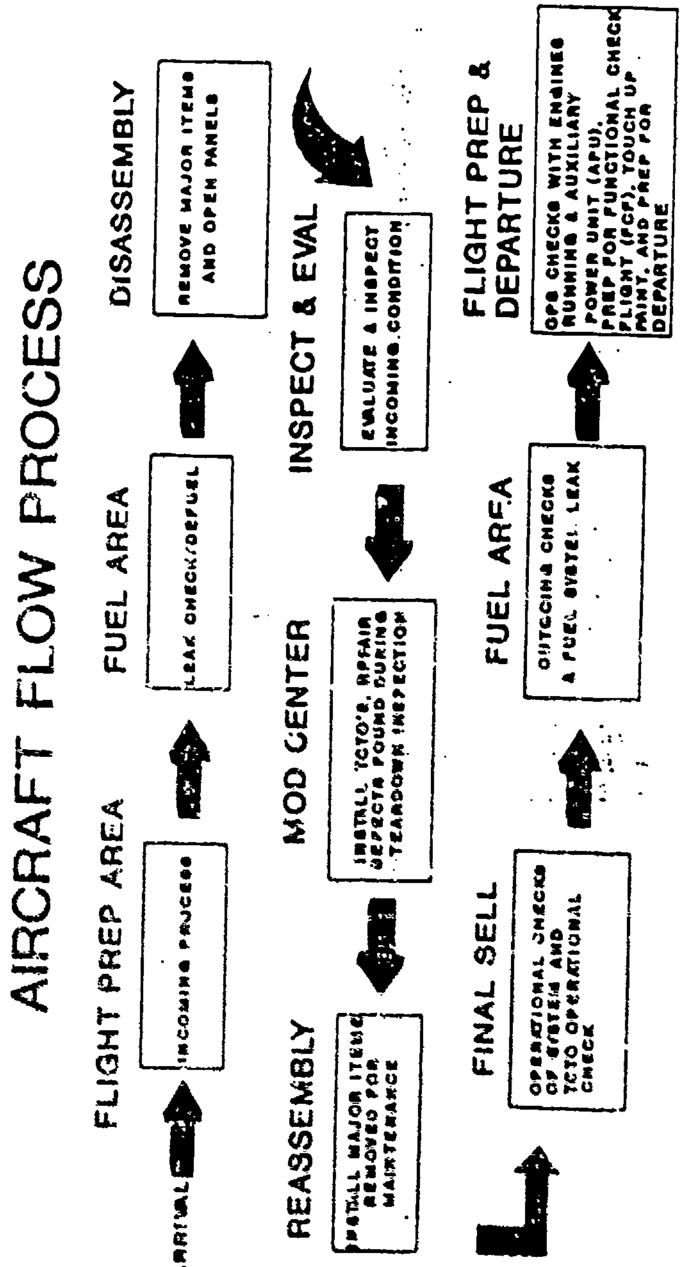


Figure IV-76. A-10 Depot Maintenance Flow

Commodities Directorate and Avionics Division Overview

Organization and Workload

SM-ALC's commodities directorate (LI) employs 1236 people and consists of four divisions - aircraft electrical and ground power, pneudraulics, avionics, and program control. As shown by the chart in Figure IV-77, a contracting division is matrixed to the directorate. Virtually all of LI's workload is scheduled MISTR maintenance. The directorate has recently converted to the alternate work schedule. The majority of personnel work a day shift, with the night shift being used primarily for accomplishing final testing. While the bulk of the directorate's work is in support of USAF aircraft, a small percentage of repair is for Navy, Army, and FMS (foreign military sales) components.

LI Engineering

LI's engineers have initiated and have under consideration a number of innovative ideas and programs. To speed the processing of engineering change requests, the directorate is working on establishing liaison engineering authority with the ALCs that have item management responsibility for the parts LI repairs (primarily OC-ALC and OO-ALC). So far, this authority has been established with SA-ALC on four major items. Thus, LI engineers may now coordinate change requests with SA-ALC engineers over the telephone and by fax and approve the changes themselves. LI's chief engineer is also creating a project engineering

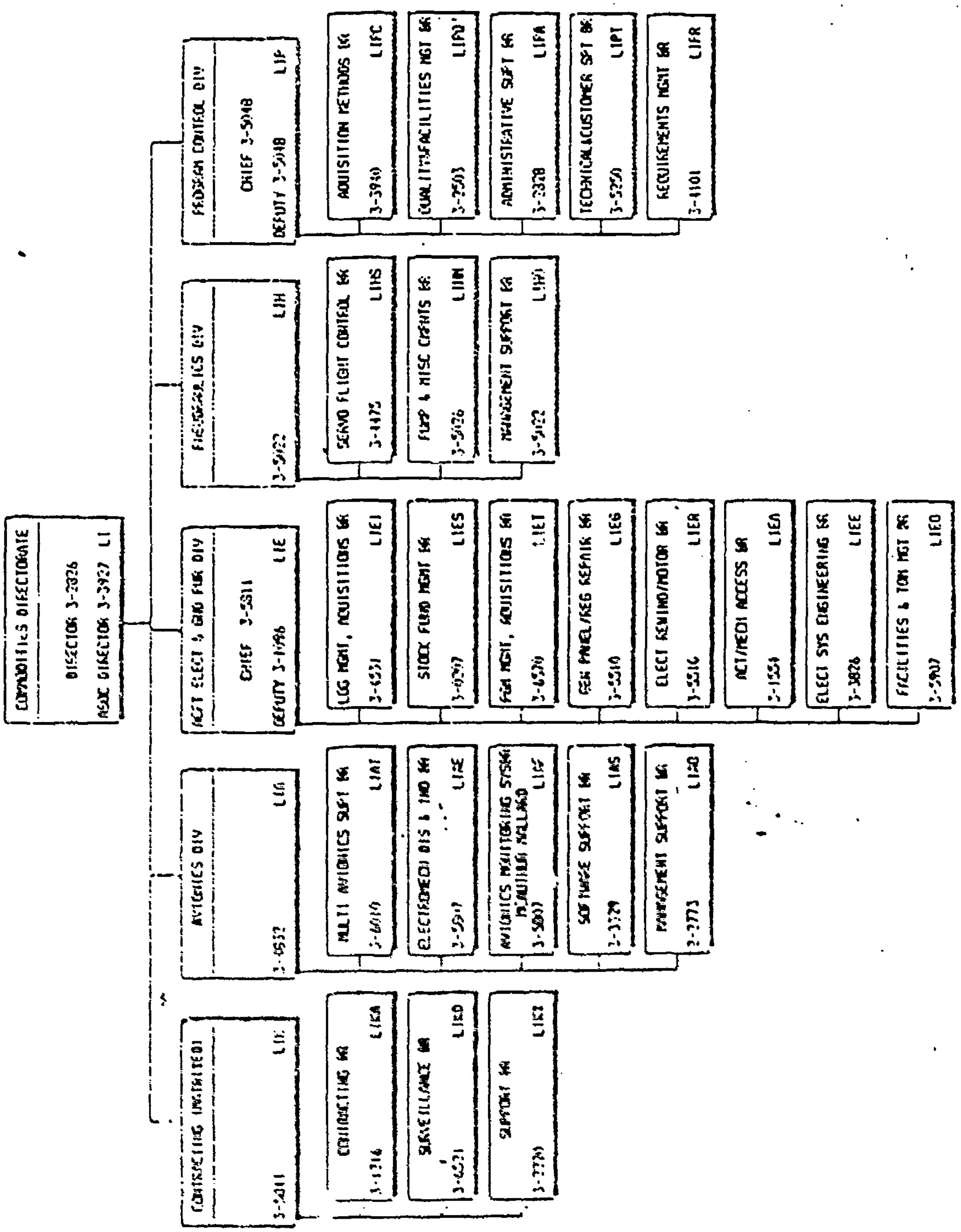


Figure IV-77. SM-ALC Commodities Directorate Organizational Chart

management and tracking system. This system would be used to determine the net present value and payback for various projects and the order for working them. It would include a historical database and, by flagging projects outside of an acceptable schedule completion window, also allow managers to easily track project progress. In addition, LI has AFLC's only organic variability reduction program. Employing tools like Quality Function Deployment (QFD) and Taguchi Design of Experiments (DOE), the variability reduction PAT has substantially improved the repair process for F-111 electrical generators. A repair flow chart for one of the main components in this generator is provided in Figure IV-78. However, as LI's chief engineer noted, for long-term process improvement, bar coding and serial number tracking are essential. AFLC needs to implement an automated data collection system that collects data across an entire population and is not a burden on mechanics.

LI's Avionics Division

Serial number tracking is especially useful in avionics repair. LI's avionics division (LIA) is the overhaul center for in-flight display systems for all USAF aircraft and occasionally repairs some Navy F-14 and Army helicopter components. Seventy percent of the items in LIA's workload are managed by OC-ALC. The division's 346 personnel are divided among five branches - multi avionics support, electromechanical displays and indicators, avionics monitoring systems, software support, and management

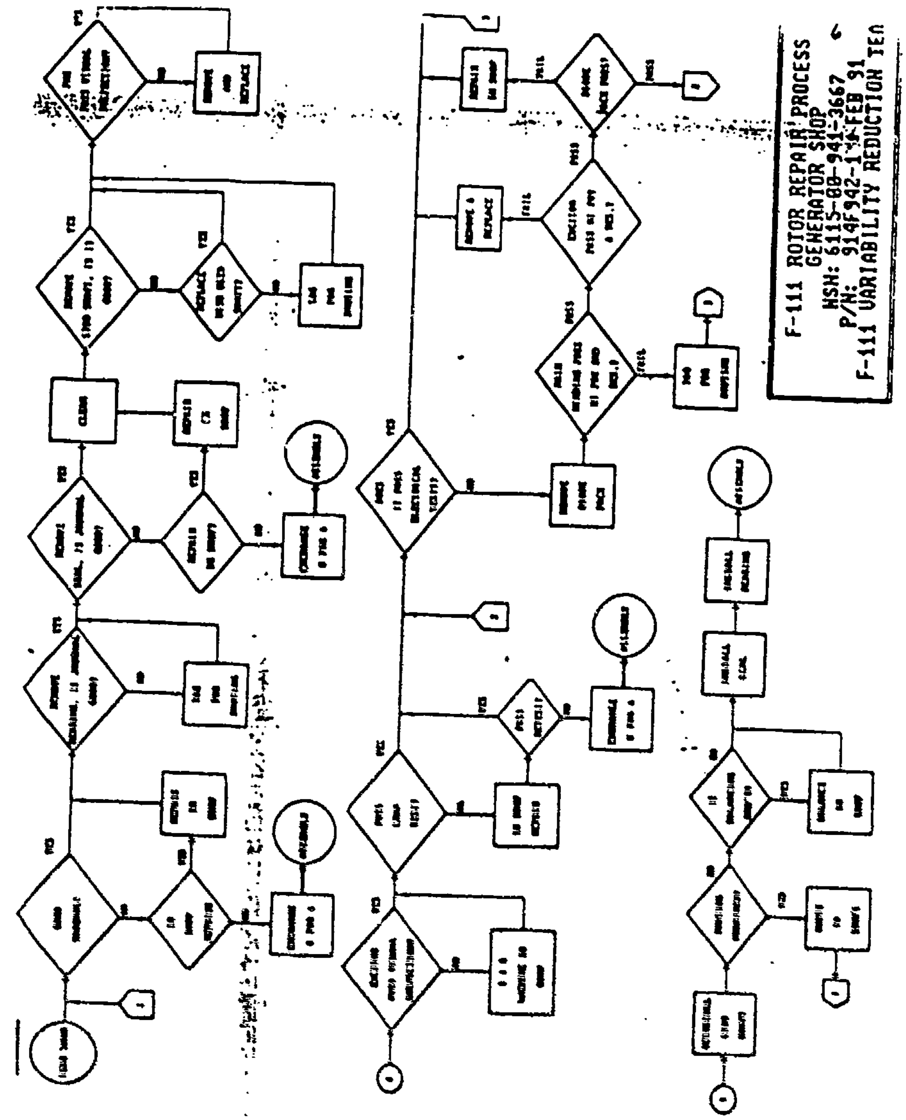


Figure IV-78. Rotor Repair Flow for F-111 Electrical Generator

support. LIA has a product line organization in which the schedulers and planners are located on the shop floor and work directly for the product line (branch) chiefs. The division has its own software engineers, who work closely with technicians to develop organic repair capabilities. In fact, LIA is now doing depot repair on seven workloads previously contracted to private industry. Because 30 percent of the division's workforce has been cross trained, branch chiefs often move people between branches. Branch chiefs have been empowered to resolve all workload problems. As a result, the division chief can concentrate on larger issues related to competition, vendor selection, and personnel policies.

Overview of TI's Organizations

TI Organization and Workload

The Technology and Industrial Support Directorate (TI) is a diverse organization with seven divisions and 2000 personnel. The chart in Figure IV-79 shows TI's divisions and branches. Like LI, TI employees are on the alternate work schedule. Plant management, non-destructive inspection, job shop manufacturing and repair of aircraft structural components, management of the MICs, and printing and distribution of technical order changes are just a few of the functions performed by TI personnel. The directorate also has technology application program management responsibility in three areas - advanced composites, microelectronics, and photonics. Some of TI's engineers

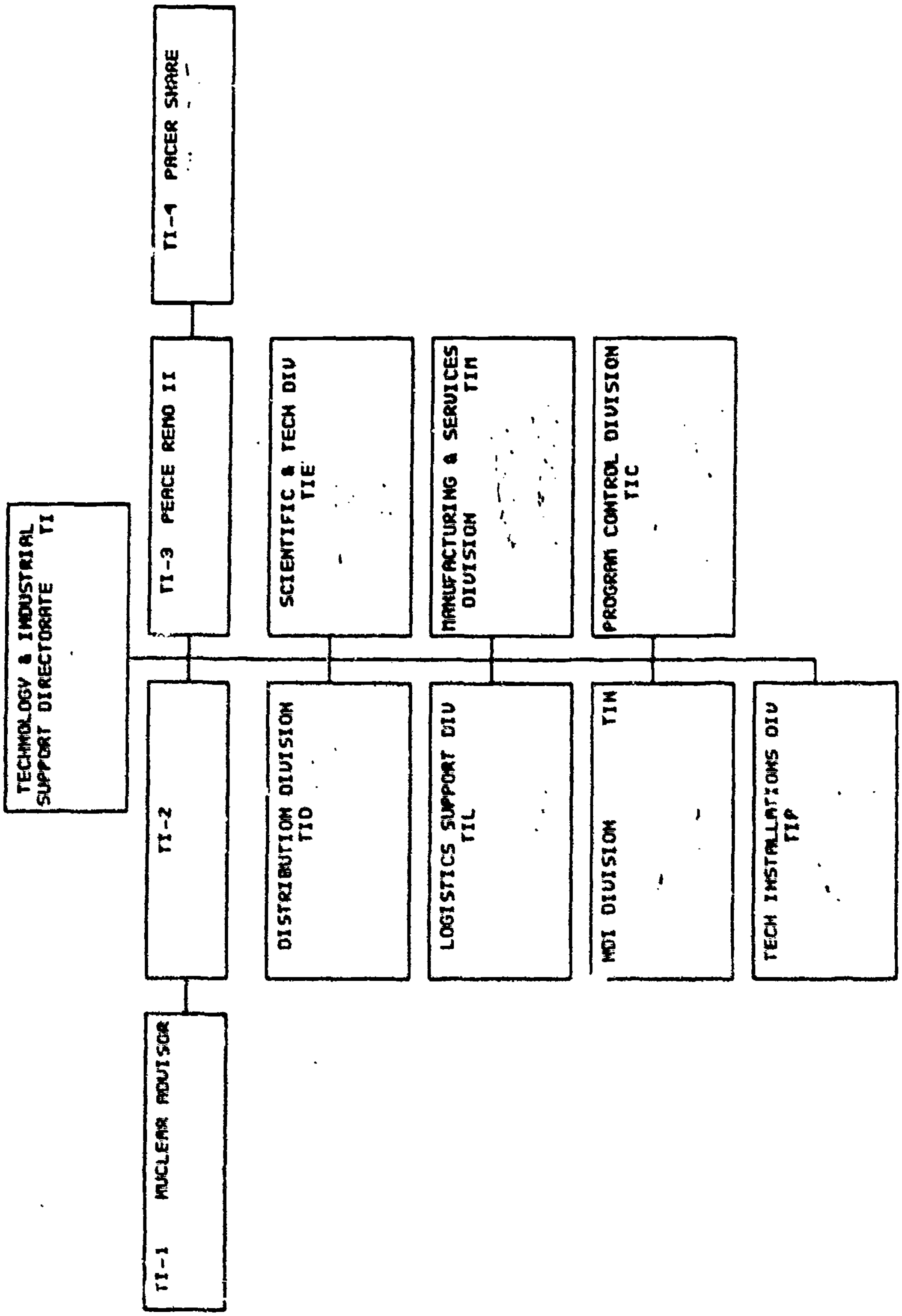


Figure IV-79. TI Directorate Organizational Chart

were part of a software PAT which compiled a book that defines the software engineering process, explains how to document it, and provides tools for tracking project progress. Following the guidelines in this book, customer involvement and user inputs are obtained at the beginning of a project and accountability is brought to management. In addition, workers are able to see how their tasks fit into the overall project. In essence, the book provides a roadmap which helps customers, managers, and project team members understand the complexity of a project, including the organizations involved and the types of funding required. The test case for this book is the A-10 LASTE modification, and, thus far, development of the A-10 LASTE operational flight programs (OFPs) is proceeding smoothly. Having a well-defined software engineering process will enable SM-ALC to develop all A-10 OFPs in-house and to become more competitive for software development in general.

Manufacturing and Services Division and Advanced Structures Branch

Because the A-10 and F-111 workloads will soon be declining, TI is looking to other DOD customers for additional work for its NDI facility and its manufacturing and services division (TIM). TIM's aircraft advanced structures branch (TIMC) is expanding to handle the Navy workload it recently acquired. Personnel are being loaned to TIMC from the division's manufacturing branch, which has seen its work decrease to the point where the center is

debating about the extent of manufacturing capability to be retained. In addition to the two branches already mentioned, TIM's 600 personnel are assigned to the industrial support, MIC material support, facilities and technology, and production control branches. Unscheduled maintenance represents 50 percent of the division's workload and 80 percent of the manufacturing branch's work.

By contrast, 95 percent of TIMC's workload is scheduled MISTR repairs, the bulk of which support the A-10 and F-111 aircraft. The branch's 160 personnel perform repairs using three types of technology - conventional bonded repair, composites, and conventional fiberglass. To accommodate its increasing workload, TIMC recently acquired a lot of new equipment. A branch PAT composed entirely of workers and first-line supervisors studied repair process flows and designed the shop layout for these machines. Another branch PAT is investigating how to streamline material ordering. Finally, with two people assigned to cost management on a full-time basis, TIMC is the only TIM branch doing cost analysis.

Competitive Edges

Because, at the directorate level, the same sets of competitive edge rankings were used for the F-111 and A-10 cases, the reader should refer to the F-111 case for a discussion of the directorate rankings. Although this case contains the same LA aircraft production and program control division rankings used in the F-111 case, the LI and TI

rankings are taken from different LI and TI divisions. By criteria, the LIA and TIM rankings are identical. In this category, all four division chiefs ranked cost and delivery among the top three competitive edges and considered flexibility and innovation to be relatively unimportant. On the basis of objectives, three of the four division chiefs included cost and delivery among the three most critical edges. Overall, though, there is little agreement among the division rankings in this category. Figures IV-80 and IV-81 contain the A-10 directorate and division competitive edge rankings.

The rankings of the A-10 branch chiefs and first-line supervisors (see Figure IV-82) do not display the degree of similarity exhibited by the F-111 competitive edge rankings for these groups. By objectives, A-10 branch chiefs and first-line supervisors considered quality and cost to be the two most critical competitive edges. On the basis of criteria, the branch chiefs also ranked quality and cost as most important. However, the first-line supervisors believed that quality and delivery were the most critical edges. This difference reflects the fact that SM-ALC's branch chiefs are generally held accountable for operating expenses, while the first-line supervisors are more concerned with delivering a quality product on time. As expected, in the criteria category, both groups considered lead time to be relatively unimportant. However, innovation was ranked as the third most critical edge by these branch

Aircraft Directorate (n=1)		
Rank Order	By Objectives	By Criteria
1	Quality	Cost
2	Flexibility	Delivery
3	Innovation	Quality
4	Cost	Innovation
5	Delivery	Flexibility
6	Lead Time	Lead Time

Commodities Directorate (n=1)		
Rank Order	By Objectives	By Criteria
1	Quality	Cost
2	Delivery	Delivery
3	Cost	Quality
4	Flexibility	Lead Time
5	Innovation	Flexibility
6	Lead Time	Innovation

TI Directorate (n=1)		
Rank Order	By Objectives	By Criteria
1	Quality	Cost
2	Delivery	Quality
3	Cost	Delivery
4	Lead Time	Innovation
5	Flexibility	Flexibility
6	Innovation	Lead Time

Figure IV-80. Directorate Competitive Edge Rankings

Rank Order	LA Aircraft Production		LA Program Control	
	By Objectives	By Criteria	By Objectives	By Criteria
1	Quality	Cost	Quality	Cost
2	Delivery	Quality	Cost	Delivery
3	Innovation	Delivery	Delivery	Quality
4	Flexibility	Lead Time	Innovation	Innovation
5	Cost	Flexibility	Flexibility	Flexibility
6	Lead Time	Innovation	Lead Time	Lead Time

Rank Order	TI Manufacturing and Services		LI Avionics	
	By Objectives	By Criteria	By Objectives	By Criteria
1	Cost	Cost	Quality	Cost
2	Lead Time	Delivery	Delivery	Delivery
3	Delivery	Lead Time	Cost	Lead Time
4	Quality	Quality	Flexibility	Quality
5	Flexibility	Flexibility	Lead Time	Flexibility
6	Innovation	Innovation	Innovation	Innovation

NOTE: (n=1) for each division

Figure IV-81. Division Competitive Edge Rankings

LA, LI, and TI Branch Chiefs (n=5)				
Rank Order	By Objectives	Ranking	By Criteria	Ranking
1	Quality	1.80	Quality	1.60
2	Cost	2.20	Cost	1.80
3	Innovation	2.80	Innovation	3.80
4	Lead Time	4.00	Delivery	4.00
5	Delivery	4.80	Flexibility	4.60
6	Flexibility	5.40	Lead Time	5.20

LA, LI, and TI First-Line Sueprvisors (n=4)				
Rank Order	By Objectives	Ranking	By Criteria	Ranking
1	Quality	2.00	Quality	1.75
2	Cost	3.00	Delivery	2.75
3	Delivery	3.00	Cost	3.00
4	Flexibility	4.00	Flexibility	4.00
5	Lead Time	4.25	Lead Time	4.50
6	Innovation	4.75	Innovation	5.00

Figure IV-02. Competitive Edge Rankings by Branch Chiefs and First-Line Supervisors

chiefs. The high ranking for this element at this level of the organization was not observed in any of the other cases in this study. This ranking could indicate that innovation is being used by A-10 division chiefs as a key indicator of branch performance and/or that the thinking of these branch chiefs is particularly progressive.

Performance Criteria

A-10 Criteria

Aircraft directorate and division criteria were previously discussed in the F-111 case. Like the F-111 weapon system review, the A-10 monthly weapon system review provides data on readiness indicators, engine status, aircraft modifications, and A-10 customer reported defects. This briefing, however, includes more information on critical items and also displays the top MICAP items for the most recent month. The review identifies problem items and potentially critical items and employs three different charts to detail the status of critical items. Bar graphs are used to show the total number of critical items and critical item slippages by source of supply for each of the past 12 months. In addition, a narrative chart highlights the old and new get-well dates, the source of supply, and the problem for a number of critical items.

TI Criteria

Instead of having a formal management review, every month TI's director and associate director talk with each division about how it is progressing against its programs.

The directorate does hold monthly quality reviews that present what is being done in terms of PATs, GIFTs (good ideas for the taking), and TQM training. At division level, the TIM division holds formal monthly management reviews with each of its branches. Both workers and supervisors attend these meetings. There is no standard format for the way information is presented, but TIMC's briefing is one of the most complete in the division.

The topic areas and various subtopics covered by the TIMC briefing are summarized in Figure IV-83. The safety statistics are given for each month of the current fiscal year. The waste management charts show the waste generated by the branch in total pounds, number of 55-gallon drums, and dollar cost for each of the previous six months. The training slide lists the number of personnel that attended various courses during the most recent month. MISTR production information is categorized according to units negotiated, units scheduled, units completed, and completion percentage to date. The production section also provides information on the number of units not produced during the previous quarter, by RCC, and the reasons for the lack of production. Planning activities summarize the status of such items as temporary work orders, engineering change requests, technical order change requests, and work control document updates. "I" status refers to the five oldest work orders awaiting material. The budget slide shows the current balance for various budget categories, like office

<u>Safety</u>	<u>Planning</u>
Injuries	Planning Activities
Cumulative Disabling	"I" Status
Safety Index	<u>Quality</u>
<u>Waste Management</u>	Complaints
Waste Generation	Incoming QDRs
<u>Training</u>	Outgoing QDRs
Courses	Process Action Team
<u>Production</u>	<u>Management of Resources</u>
MISTR Production	Budget Overtime
MISTR by RCC	Profit/Loss Sick Leave
Oldest JONs	Productivity

<u>Figure IV-83</u>. TIMC Management Review Topics

supplies, training TDY, and equipment rental. The profit/loss slide outlines budgeted versus actual expenses by RCC and gives the reason for overexpenditures. The productivity data is also broken down by RCC and is simply a tally of the earned versus actual hours and the resulting effectiveness percentage.

LI Criteria

The LI directorate holds management and DMIF financial status reviews with its division chiefs once a month. The financial status reviews look at G&A overhead/material expenses and cost performance for each of the directorate's three product divisions. Targeted versus actual G&A overhead/material expenses are examined for nine categories - administrative TDY, training TDY, tuition, other equipment maintenance, miscellaneous service contracts, IPE (industrial plant equipment) maintenance, office equipment, and office supplies. Cost performance is displayed for seven accounts for various categories of supplies, tools, material, and fuels. The management review has a couple of slides on cost analysis but primarily concentrates on effectiveness and efficiency criteria. The LI management review indicators are outlined in Figure IV-84.

The LI avionics division meets with its branch chiefs on a regular basis to review production and quality performance. Each branch provides information on units scheduled versus produced (for the current quarter), critical items (for which production and/or parts problems

Effectiveness

1. Units Produced - For LI (for each quarter of current fiscal year) and by division (for the latest quarter)

2. DPSH Produced - By LI (for the year to date) and by division (for the latest month)

Efficiency

3. Direct Labor Utilization - For LI and for each division for each month of the current fiscal year

4. Direct Material Utilization - Budgeted vs actual for LI (for each quarter of current fiscal year) and by division (year to date)

5. Indirect Labor Utilization - Budgeted vs actual for LI and for each division (for each month of the current fiscal year)

6. Direct Overtime - Budgeted vs actual for LI (for each month of current fiscal year) and by division (for each quarter of current fiscal year)

7. Cost Rate Analysis - Cost performance of LI and each division according to five indicators (budgeted year-to-date DPSH, actual year-to-date DPAH, budgeted year-to-date DPEH, variance of revenue vs targeted, and variance of revenue vs cost of goods sold)

8. Material Transaction Errors - Error rate by division for the latest month

9. Suspense Material - Dollars of material in suspense status, by division, for each month of the current fiscal year

Figure IV-84. LI Management Review Indicators

exist), and workload. For each quarter of the current fiscal year, the workload chart displays negotiated hours, available capacity, capacity available with five percent overtime, manpower available, and manpower required. Quality data, primarily in the form of received versus completed QDRs, is also included in the LIA reviews.

System Constraints

Behavioral and Managerial Constraints

While market, behavioral, managerial, and logistical constraints are all present in A-10 depot maintenance, parts availability was the problem mentioned most frequently. Because many of the A-10 constraints are similar to those discussed in the other five cases in this study, they will not be discussed in as much detail as in previous cases.

After material support, the LI associate director's greatest concern is the workforce mindset. He noted that employees are cynical about TQM and reluctant to change. To overcome these behavioral barriers, the LI directorate has set up enlightenment (suggestion) boxes in the break areas and has established communication mechanisms for employees to voice their concerns. Employee forums are regularly conducted for each division, and roundtable discussions are held for first-line supervisors. Suggestions are only seen and answered by the LI director and associate director. The directorate also believes that the current performance appraisal system is detrimental to productivity and countermands TQM's teamwork approach. LI is advocating

replacing appraisals with interviews and using a promotion system similar to that of AFLC's PACER SHARE program. Of course, to eliminate appraisals would require changing the Civil Service Reform Act and several OPM policies.

The only A-10 manager that listed lack of manpower, due to the hiring freeze, as a problem was LAB's avionics branch chief. He said that a shortage of software technicians was preventing him from making adequate progress on the F-111 DFC modifications. He also pointed out that there was no money to send personnel to contractor facilities so that they could be trained to operate new equipment that the branch had recently acquired. The only other policy mentioned by A-10 managers concerned environmental regulations. The TI director admitted that the plating shop is the biggest environmental hazard at SM-ALC. A PAT is looking at how to remedy hazards in this shop.

Market and Logistical Constraints

The completion of the LASTE modification and the elimination of 150 to 200 aircraft from the A-10 inventory will cause SM-ALC's A-10 workload to decline significantly in 1993. Though A-10 depot maintenance is market-constrained in the long term, the transfer of other aircraft workloads to SM-ALC means that the aircraft directorate does not have to be concerned about this type of constraint. The TI directorate, however, is concerned about declining workloads in its manufacturing and services division (TIM). Due to long lead times and poor due date performance, TIM is

faced with a decline in local manufacturing job orders and has lost work to other SM-ALC directorates. Item managers have begun to refer local manufacturing to private vendors rather than to TI's sheet metal and machine shops. To remedy this situation, TIM has initiated a customer relations campaign with SM-ALC item managers, is considering developing a master schedule for the division, and is making a concerted effort to meet customer due dates.

A prime cause of TI's long lead times is the problems that exist with routing material through the backshops. The production chief of TIM's aircraft advanced structures branch (TIMC) listed backshop support as his number one problem and outlined the findings of a routing PAT that he headed. This PAT found that routing tags were not filled out properly, drop stations had disappeared, assets were not dropped at known drop sites, and two separate drop stations were needed for the plating shop. The TIMC production chief believes that defining and differentiating the duties of expediters, schedulers, and material controllers and using smaller transfer batches would eliminate some of the routing delays. He also recommends the establishment of a TI control room for setting priorities on TI jobs.

This supervisor was also concerned about the number of job classifications in the material support process. According to the TIMC branch chief, changes in the sourcing of TIMC's component parts and in material ordering procedures were hampering material support. A number of the

parts that TIMC formerly obtained from LA's service branch must now be procured through private vendors at a higher cost and with longer lead times. Changes in ordering procedures stem from transferring management of the MICs to TI and item management responsibility for more classes of items to DLA.

Parts availability was also considered to be the most critical constraint in LI's avionics division. The LIA chief pointed out that, because the parts acquisition process is so cumbersome, it is impossible to react quickly enough to satisfy the requirements of the division's constantly changing workloads. Due to the greater funding uncertainties and fluctuations during the past three years, workload content and quantity have become much more dynamic. Thus, it is increasingly difficult to preposition parts and material. This division is also concerned about future workload assignments. Although LIA has AFLC's largest concentration of expertise on electromechanical repair, more and more avionics repair involves digital displays. Because WR-ALC already has the digital workload, the LIA chief believes that his division's workload could begin to decline. The division has assumed seven workloads from private contractors and has established its RCCs at the branch (four-digit), instead of the section (five-digit), level. By placing its RCCs at a higher level, the division can budget against a bigger pool of resources and better handle workload variability. Also, with a greater variety

of workloads in each RCC, it is easier for individual RCCs to show a profit. Finally, to shorten process flow times and increase MTBR, the division is using more commercial test equipment. While most of the government-procured test equipment isolates one fault at a time, commercial testers can check all wiring and circuit cards in a matter of minutes. By using commercial testers for the repair of A-10 central air data computers, the quarterly workload for this item has decreased from four persons' worth of work to the work of just one-half person.

CHAPTER V

CASE STUDY ANALYSIS

Introduction

This chapter consists of two separate sections for within-case analysis and cross-case analysis. In the first section, each case is analyzed with respect to the research questions. In the second section, comparison tables and summary diagrams are used to highlight the similarities and differences found among the six research participants on the four research questions. The cross-case study analysis enhances the generalizability of this study (Miles & Huberman, 1984) and was used to aid in developing the propositions and depot maintenance performance model presented in Chapter VI. Data collected from pre-visit questionnaires and on-site surveys and interviews formed the basis for the detailed case studies. The data was used to assess the elements, or competitive edges, on which each depot maintenance organization competes, its system constraints, and the strategies (i.e., goals and objectives) and performance criteria (i.e., management indicators) it currently employs. Each case study was then analyzed against the following dissertation research questions:

(1) Is there congruence between the goals of the Air Force Logistics Command (AFLC) and the depot-level and directorate-level objectives of its aircraft repair depots?

(2) Do managers at the directorate, division, branch, and first-line supervision levels agree on the ranking of the criticality of the competitive edges for accomplishing depot maintenance?

(3) Do performance criteria used at the directorate, division, and branch levels support the accomplishment of AFLC goals and directorate and depot objectives? If not, what are some criteria that would better support these organizations' objectives?

(4) What types of constraints exist in these depots, and how do these constraints impact depot performance?

For the first three questions, the results of the survey instruments were summarized in the form of tables. As part of the first research question, directorate and division chiefs were asked to rate the extent to which they believed their ALC (depot) and directorate objectives supported AFLC's goals. A rating scale of 1 to 4 was used, with 1 indicating no extent, 2 designating slight extent, 3 representing significant extent, and 4 equating to great extent. Mann-Whitney U tests were conducted on these survey results to determine whether significant differences existed between the mean rankings of aircraft managers and those from the supporting directorates of commodities and TI. For each case, the numerical ratings on this question and the

results of the Mann-Whitney test are given. For all cases except A-10 depot maintenance, the first section of the within-case analysis also provides a goal comparison chart comparing the goals of the particular ALC with the goals and objectives of the ALC's directorates examined in that case.

For the second research question, managers at four levels - directorate, division, branch, and first-line supervision - were asked to rank the importance of the competitive edges of cost, quality, lead time, delivery, product/process flexibility, and product/process innovation for accomplishing depot maintenance on their particular type of aircraft. One set of rankings was based upon unit objectives, while the other set was based on the criteria, or management indicators, used to report unit performance. To determine whether significant differences existed between the mean rankings of the competitive edges themselves, Friedman Two-Way Analysis of Variance of Ranks tests were conducted on the two sets of rankings. Also, Bonferroni Pairwise Comparison tests were employed to highlight where the differences existed. In addition, median tests were used to determine whether differences existed between higher-level (directorate and division chiefs) and lower-level (branch chiefs and first-line supervisors) directorate managers on the rankings of individual competitive edges. Finally, median tests were used to ascertain whether differences existed between all levels of aircraft managers and of managers from supporting

directorates on individual competitive edge rankings. For each case, the results of the Friedman tests, Bonferroni tests, and median tests for which significant differences existed are analyzed and displayed in tabular form.

As part of the third research question, managers at four levels - directorate, division, branch, and first-line supervision - were asked to rank the extent to which they believed their organization's management indicators supported their depot and directorate objectives and command goals. A rating scale of 1 to 4 was used, with 1 representing no extent, 2 indicating slight extent, 3 designating significant extent, and 4 devoting great extent. Mann-Whitney U tests were conducted on the survey results to determine whether significant differences existed between the mean rankings of each of the four groups of managers. For each case, the numerical ratings on this question and the results of the Mann-Whitney U tests are provided. The second part of this research question, performance criteria that better support depot and directorate objectives, is addressed for all depot maintenance organizations as part of proposition 15 in Chapter VI (refer to Figure VI-4).

For the fourth research question, separate effect-cause-effect (ECE) diagrams were developed for C-130 and C-141 depot maintenance and for depot maintenance at OO-ALC and SM-ALC. The ECE for OO-ALC combined data from the F-4 and F-16 cases, while the SM-ALC ECE was based on data from the F-111 and A-10 cases. These four diagrams became the

basis for a combined ECE diagram for AFLC depot maintenance, which is presented in the cross-case analysis section. The within-case analysis is presented in the following sequence: C-130 depot maintenance, C-141 depot maintenance, F-4 depot maintenance, F-16 depot maintenance, F-111 depot maintenance, and A-10 depot maintenance.

Within-Case Analysis

C-130 Depot Maintenance

AFLC Goals and Depot Objectives

Figure V-1 summarizes the goals of AFLC, the WR-ALC commander's objectives for C-130 depot maintenance, the C-130 directorate's goals and objectives, and the objectives of the Technology and Industrial Support (TI) Directorate. Figure V-2 provides a comparison of the most frequently mentioned goals/objectives across command, center, and directorate levels. The AFLC goals are very broad and seem to closely resemble some vision statements noted in the literature (Harvey, 1988). In summary, AFLC goals listed under the people category relate to empowering command personnel to do their jobs, user support goals involve making customer satisfaction the first priority, and quality goals consist of making continuous improvement a way of life. Customer satisfaction is certainly a worthy goal, and enhancement of requirements forecasting is badly needed. Likewise, including all AFLC processes, especially engineering and contracting, in the quality effort is definitely important. However, the remaining quality and

AFLC Goals	WR-ALC Goal
People	Operate Profitably
Quality of Life	Provide On-time Delivery
Recognition	Provide Quality Products
Personal Accountability	Ensure Wartime Capability
Trust People	C-130 Directorate Objectives
Warriors	Process Improvement
User Support	Competitive for PDM
Customer Satisfaction	Sustain 30 PDMs Annually
Organizational Realignments	Decrease C-130s on Ramp to 10
Requirements Forecasting	Decrease PDM Flow Days to 100
Quality	Reduce Quality Defects by 10%
Quality First	Measure Rework
Involve Everyone	Break Even in DMIF
All AFLC Processes	Recognize "Superstars"
Continuous Improvement	Train All in TQM by Dec. 1992
Pride of Workmanship	TI Directorate Goals
and Ownership	Reduce Production Cost
	Ensure Customer Satisfaction
	Increase OPMD
	Decrease F-15 Wing Flow Days
	Assure Quality Products
	Streamline Engineering
	Zero Hazardous Waste
	Violations

Figure V-1. Summary of C-130 Organizational Goals and Depot Objectives

Goals or Objectives	AFLC	WR-ALC	C-130	TI
Profitability		x	x	x
Quality/TQM	x	x	x	x
Timeliness		x	x	x
Customer Satisfaction	x	x	x	x
Continuous Improvement	x		x	
Personal Accountability	x			

x = Organization has a goal/objective pertaining to goal/objective listed in the left-hand column

Figure V-2. C-130 Goals and Objectives by Organizational Levels

people goals are merely prerequisites, or necessary conditions, essential for success in any profit or non-profit organization.

The WR-ALC goal is to operate profitably while providing the customer with the best quality products and services on time at best value and to ensure the long-term wartime capability of the center. The C-130 director believes that the objectives of his directorate and WR-ALC support AFLC goals to a significant degree. In addition, the goals and objectives of the C-130 directorate closely parallel the three WR-ALC objectives previously mentioned. The C-130 director sees process improvement as the key to reducing concerns about cost and schedule, the top two WR-ALC objectives. Also, because the C-130 director defines quality as customer satisfaction, customer satisfaction is included as a C-130 directorate objective in Figure V-2.

Similarly, the goals of the TI directorate strongly relate to WR-ALC's objectives on cost, schedule, and quality. The fifth TI goal, assure quality products, could probably be included as part of the second goal, ensure customer satisfaction. The sixth goal, streamline engineering, could be improved by giving engineers a specific target regarding a particular process, such as first article approvals. The third goal on increasing OPMD, however, is the most questionable one. Output per paid manday is a performance criterion which often conflicts with

the achievement of other AFLC, ALC, and TI objectives concerned with schedule and quality.

Even though quality is the only goal or objective emphasized at all four organizational levels, the center and directorate objectives generally support AFLC's overall emphasis on customer satisfaction. Indeed, the center and directorate objectives exhibit high agreement on the importance of achieving goals related to cost, quality, and timeliness (delivery or schedule). Because cost is typically measured and of greater concern at higher organizational levels, it is surprising that AFLC does not mention cost in any of its goals. Finally, due to the WR-ALC center commander's recent proposals to revise personnel performance appraisal criteria, managers may soon begin to include personal accountability, an AFLC goal, as an objective for their organizations.

Figure V-3 shows the numerical rating given by the C-130 and TI directorate and division chiefs on the congruency between AFLC goals and depot objectives. The large p-value associated with the Mann-Whitney U test indicates that no significant differences existed between the rankings of the C-130 aircraft and support (TI) managers at the .01 and .05 levels of significance. Looking at the ratings and the average ranks, it can be seen that a majority of these managers believe that their command, center, and directorate goals and objectives support each other to a significant degree.

Numerical Ratings		
Unit	Directorate	Division
C-130	3	3
TI	3	3,4
Average	3.00	3.33

Mann-Whitney U Test				
Function	Rank Sum	Sample Size	U Stat	Average Rank
Aircraft	5.00	2	2.000	2.5
Support	10.00	3	4.000	3.3
Total	15.00	5		
Two-Tailed P-Value for Normal Approximation				0.7728

Figure V-3. Numerical Ratings and Mann-Whitney U Test for Congruency of AFLC Goals and Depot Objectives

Competitive Edges

Managers at four levels - directorate, division, branch, and first-line supervision - were asked to rank the importance of the competitive edges of cost, quality, delivery, lead time, product/process flexibility, and product/process innovation for accomplishing C-130 depot maintenance. One set of rankings was based on unit objectives, while the other set was based on the criteria, or management indicators, used to report unit performance. In general, managers at lower levels of the organization had difficulty differentiating these rankings for the objectives and criteria categories. Also, across organizational levels, the rankings by criteria exhibit higher agreement than the rankings by objectives. This fact may indicate that managers at all levels are fully aware of how their unit performance is evaluated but are less cognizant of unit objectives.

Friedman Two-Way Analysis of Variance of Ranks tests were conducted to determine whether significant differences existed between the mean rankings of the competitive edges themselves. The results of these tests, shown in Figure V-4, revealed that, on the basis of both objectives and criteria, significant differences existed between the mean ranks of the competitive edges themselves at the .01 and .05 significance levels. This conclusion was based on the extremely small p-values associated with the competitive edges factor (i.e., reject Ho). The Bonferroni test results

Friedman Two-Way Nonparametric Analysis of Ranks		
Competitive Edges	Mean Rank	Sample Size
Cost	3.18	17
Quality	1.18	17
Lead Time	4.24	17
Delivery	2.59	17
Flexibility	4.82	17
Innovation	5.00	17
Friedman Statistic		52.83
P-Value, Chi-Squared Approximation		0.0000
Degrees of Freedom		5

Friedman Two-Way Nonparametric Analysis of Ranks		
Competitive Edges	Mean Rank	Sample Size
Cost	2.41	17
Quality	1.59	17
Lead Time	4.41	17
Delivery	2.41	17
Flexibility	5.06	17
Innovation	5.12	17
Friedman Statistic		57.81
P-Value, Chi-Squared Approximation		0.0000
Degrees of Freedom		5

Figure V-4. Friedman Two-Way Analysis of Variance of Ranks Results: C-130 Depot Maintenance Competitive Edge Rankings by Objectives (top) and by Criteria (bottom)

in Figure V-5 highlight where the differences exist. On the basis of unit objectives, quality and delivery are considered to be the most critical competitive edges, while lead time, flexibility, and innovation are regarded as the least important edges. Cost seems to be ranked as neither critical nor unimportant. On the basis of performance criteria, quality, delivery, and cost, in that order, are clearly considered to be more important than lead time, flexibility, and innovation. This difference in rankings is consistent with the performance criteria employed by the C-130 and TI directorates and with the data provided in Chapter IV.

Median tests were used to ascertain whether differences existed between higher-level (directorate and division chiefs) and lower-level (branch chiefs and first-line supervisors) C-130 and TI managers on the rankings of individual competitive edges. Based on these two organizational levels, no significant differences existed between the ranks of the competitive edges at the .01 and .05 levels of significance. Median tests were also used to determine whether differences existed between all levels of C-130 aircraft and support (TI) managers on individual competitive edge rankings. Based on these two organizational functions, there were no significant differences at the .01 or .05 significance levels.

C-130 Pairwise Comparison of Competitive Edge Means by Objectives

Quality	Delivery	Cost	Lead Time	Flexibility	Innovation
1.18	2.59	3.18	4.24	4.82	5.00

NOTE: Means which are underlined are not significantly different

C-130 Pairwise Comparison of Competitive Edge Means by Objectives

Quality	Delivery	Cost	Lead Time	Flexibility	Innovation
1.59	2.41	2.41	4.41	5.06	5.12

NOTE: Means which are underlined are not significantly different

Figure V-5. Bonferroni Pairwise Comparison Results

<u>Performance Criteria</u>

Directorate, division, and branch chiefs and first-line supervisors were asked to rate the extent to which they believed their organizations' management indicators supported their depot and directorate objectives and command goals. The actual ratings of directors and the C-130 production chief and the average ratings given by branch chiefs, first-line supervisors, and the two TI division chiefs are reported in Figure V-6. Mann-Whitney U tests were conducted on the survey results to determine whether significant differences existed between the mean rankings of each of the four groups of managers. The results of these tests, shown in Figure V-7, indicate that, at the .01 and .05 significance levels, no significant differences existed between the mean rankings of the managers at the four different levels. This conclusion was based on the large p-values associated with each test. On the basis of p-values, the agreement between the branch chief and first-line supervisor rankings is especially strong.

Until recently, the productivity measurement matrix was the primary instrument for reporting ALC performance to AFLC headquarters. With more than twenty weighted performance criteria in three major categories and a multitude of subcategories, this matrix was too complex for most managers to use and understand. Many of the criteria in this matrix, like OPMD, tended to be oriented toward measuring efficiency, rather than effectiveness, and promoted the

Congruency of Performance Criteria and Depot Objectives				
Level/Org	Directorate	Division	Branch	First-Line
C-130	3	3	3.00	2.67
TI	2	4	3.33	3.67

Figure V-6. C-130 Depot Maintenance Ratings for Congruency of Performance Criteria and Depot Objectives by Organizational Levels

Directorate -vs- Division Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Directorate	3.500	2	5.000E-01	1.8
Division	11.50	3	5.500	3.8
Total	15.00	5		
Two-Tailed P-Value for Normal Approximation				0.2482

Directorate -vs- Branch Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Directorate	5.50	2	2.500	2.8
Branch	30.50	6	9.500	5.1
Total	36.00	8		
Two-Tailed P-Value for Normal Approximation				0.3173

Directorate -vs- First-Line Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Directorate	6.00	2	3.000	3.0
First-Line	30.00	6	9.000	5.0
Total	36.00	8		
Two-Tailed P-Value for Normal Approximation				0.4047

Figure V-7. Mann-Whitney U Test Results for Congruency of Performance Criteria and Depot Objectives by Organizational Levels

Division -vs- Branch Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Division	19.50	3	13.50	6.5
Branch	25.50	6	4.50	4.3
Total	45.00	9		
Two-Tailed P-Value for Normal Approximation				0.3017

Division -vs- First-Line Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Division	18.50	3	12.500	6.2
First-Line	26.50	6	5.500	4.4
Total	45.00	9		
Two-Tailed P-Value for Normal Approximation				0.4386

Branch -vs- First-Line Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Branch	38.50	6	17.500	6.4
First-Line	39.50	6	18.500	6.6
Total	78.00	12		
Two-Tailed P-Value for Normal Approximation				1.0000

<u>Figure V-7.</u> Mann-Whitney U Test Results for Congruency of Performance Criteria and Depot Objectives by Organizational Levels (Cont'd)

buildup of excess inventory. Few, if any, of the criteria told the command whether the right parts and the right aircraft were repaired for customers. The production/ timeliness measures tended to promote "cherry picking", or working the easiest jobs first. In addition, over one-third of the matrix's weight was in the resources category, an area which has little direct relation to customer satisfaction and aircraft/MISTR production. Furthermore, many of the criteria in this category, such as manpower utilization and cost of mishaps, were gross measures that generally made an ALC look good but masked the specific areas where problems may have existed.

The DDPMS criteria place more emphasis on quality and innovation and seem to be an improvement over existing AFLC depot maintenance criteria. However, nearly all of the criteria are highly aggregated cost-based or efficiency-related ratios that are structured along the lines of the former AFLC functional organizations. Also, the current guidance provided on the data to use in compiling some of these ratios, particularly the cost of quality and conformance/non-conformance ratios, is quite vague. On the other hand, the DDMC is to be commended for including a qualitative measure on technical and managerial innovation in the DDPMS. Never before have the ALCs been required to report innovative techniques on a regular basis.

Like the AFLC productivity matrix, much of the information presented in the current version of the monthly

WR-ALC Management Review is too aggregated to be meaningful. Rather than focusing on throughput and customer satisfaction, the briefing is oriented toward labor efficiency and cost-based measures. However, the fact that inventory is finally receiving depot-level attention is noteworthy. Nevertheless, despite the command emphasis on quality and customer satisfaction and WR-ALC's emphasis on flow day reduction, the briefing does not contain a single chart showing either quality or delivery indicators. Fortunately, the center commander is currently changing the format for this briefing. He is requesting that future Management Reviews focus on center constraints and on measures related to the global criteria of throughput, inventory, and operating expense.

In contrast, the C-130 Product Directorate Monthly Management Review is strongly customer-oriented. The briefing examines the throughput and due date performance of the directorate's aircraft production, engineering, and contracting functions. The criteria and topics addressed in this review are tied directly to the C-130 directorate's goals and objectives, particularly the cost minimization objective. An entire section of the briefing is devoted to financial management. The briefing focuses on trends and gives the center commander a good idea of how well the C-130 directorate is progressing toward its objectives and those of WR-ALC and the command. In addition, a majority of the data is effectively presented in the form of bar graphs and

pie charts. Consequently, critical information is immediately obvious and quickly grasped by those viewing the briefing.

Similarly, the TI Monthly Management Review presents information that is directly related to each of TI's seven goals. Although forty percent of the charts in this briefing address production cost, the briefing does represent a serious effort to track performance in areas previously given little attention, such as quality, engineering, and environmental support. The review of the delivery of routed items, items which are removed from an aircraft on the PDM line, repaired, and returned to the PDM line, is especially notable.

Unfortunately, the least change in performance measurement in the C-130 and TI directorates has been at the division and branch levels. An efficiency measure, labor effectiveness, is still the key performance criterion used at these levels. This criterion is in conflict with the flow day and critical item status measures these areas use to evaluate customer support. However, the strategy chart in the C-130 production division's monthly management review does represent a worthy attempt to identify how the division plans to accomplish its mission. Until recently, such a chart never would have been developed at this level of the organization.

In summary, the AFLC and WR-ALC performance measurement systems are undergoing tremendous change. Although

efficiency indicators are still tracked and briefed at all levels, quality and cost indicators are receiving much more attention than in the recent past. Unfortunately, individuals at the division and branch levels generally do not appear to be very interested in performance measurement. They seem to be content with reporting whatever information they are told to report. Fortunately, such managers as the directors of the avionics and C-130 directorates are aware of the uselessness of efficiency indicators and the need for performance criteria to support an organization's goals and strategic objectives. Even more importantly, by conducting in-house training sessions and expressing their concerns to AFLC, they are actively reorienting the thinking of their commanders and their personnel.

<u>System Constraints</u>

The diagram in Figure V-8 shows the impact of various WR-ALC constraints on C-130 depot maintenance performance. Throughput (T), inventory (I), and operating expense (OE) are the three criteria used to measure C-130 depot maintenance performance. To aid the reader, the blocks in Figure V-8 have been numbered, and these numbers will be referenced (shown in parentheses) throughout the following discussion. Reductions in T and increases in I and OE can be traced to five core problems - emphasis on meeting local efficiencies in TI's backshops (1), future budgets being based on past expenditures (17), data from the G019 and D041 systems not reflecting current demand (31), OPM personnel

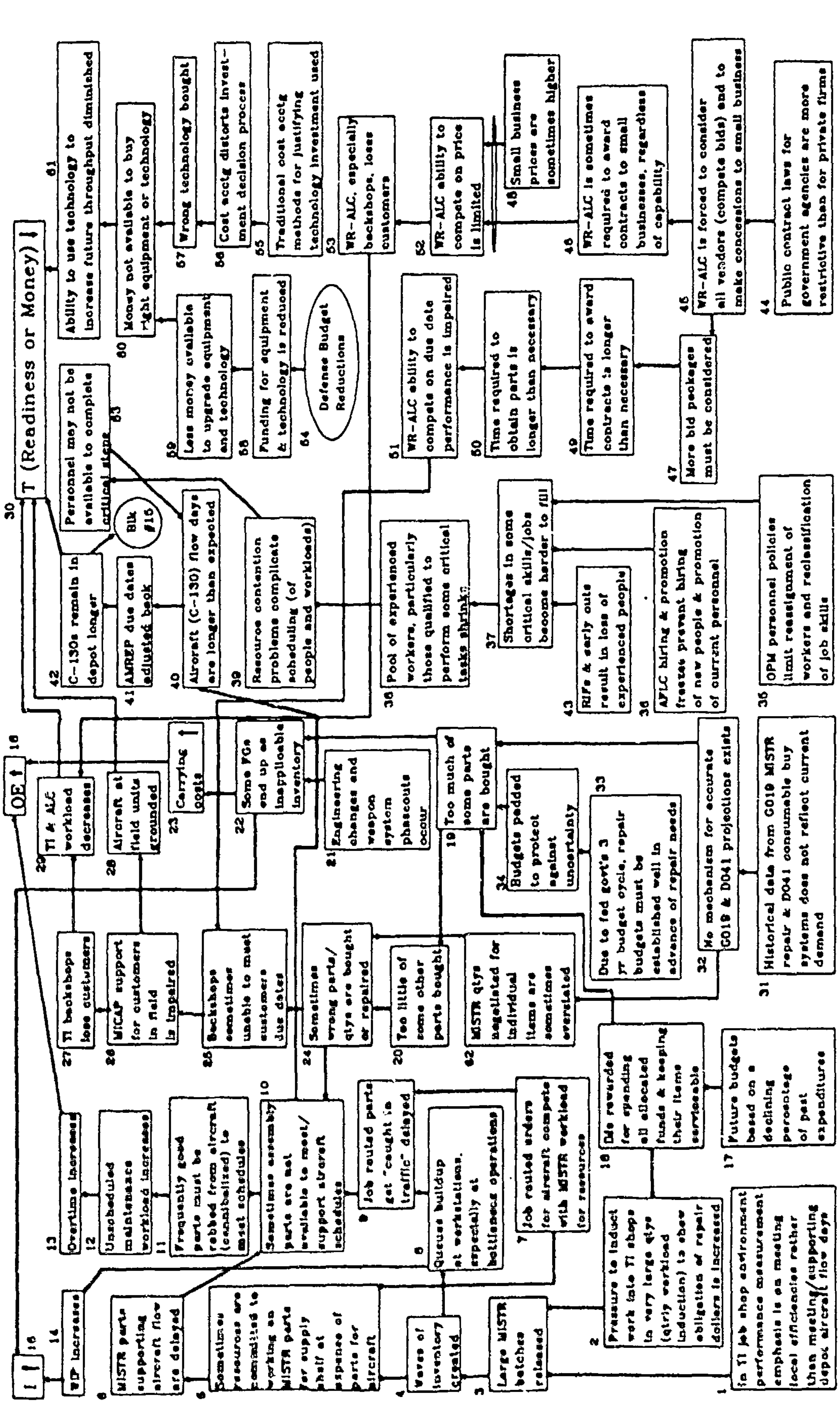


Figure V-8. ECE Diagram for C-130 Depot Maintenance

policies limiting worker reassignment and job skill classification (35), and restrictive public contract laws (44). The first two core problems (1 and 17), as well as the core driver in (55), can be traced to traditional cost accounting philosophy.

The emphasis in the TI job shops on meeting efficiencies (1) and the pressure from item managers to induct work in large quantities (2) cause large MISTR batches to be released (3), which creates waves of inventory (4) and causes queues to build up at workstations (8). As a result, WIP increases (14) and therefore overall inventory increases (15). Due to the waves of inventory (4) and the fact that job routed orders for aircraft compete with MISTR workload for resources (7), sometimes resources are committed to working on MISTR parts for the supply shelf at the expense of parts for aircraft (5). Consequently, MISTR parts supporting aircraft flow are delayed (6). Because of the lengthy queues at workstations (8) and the fact that job routed orders for aircraft compete with the MISTR workload for resources (7), job routed parts also get delayed (9). The delays for both MISTR (6) and job routed parts (9) sometimes cause assembly parts to not be available to meet aircraft schedules (10). Necessary conditions present in AFLC depot maintenance (see Figure V-9) also impact the availability of assembly parts for AMREP schedules. Consequently, when assembly parts do not meet AMREP schedules, often good parts must be robbed from aircraft

Necessary Conditions to Support Shop Scheduling

1. Parts scheduled through shops are repair parts needed to assemble PDM aircraft and meet AMREP schedules.

2. Parts scheduled through shops are large batches for spare parts replenishment system (MISTR).

3. Prior to disassembly, there is always uncertainty concerning what parts/work will actually be required.

Figure V-9. Necessary Conditions for AFLC Depot Maintenance

(11), which causes the unscheduled maintenance workload to increase (12). More unscheduled maintenance leads to more overtime (13) and increased operating expenses (16).

The second core problem, the basing of future budgets on a declining percentage of past expenditures (17), causes item managers to be measured on program execution and rewarded for spending all their allocated funds (18). Consequently, item managers buy too many of some parts (19) and too few of some other parts (20), which means that sometimes the wrong parts or the wrong quantities of parts are bought (24). In addition, because repair budgets must be established well in advance of repair needs (33), budgets are padded to protect against uncertainty (34), causing too many of some parts to be bought (19).

The third core constraint, the fact that G019 and D041 data does not reflect current demand (31), also impacts parts procurement. Due to this problem (31), no mechanism for accurate G019 projections exists (32), so negotiated MISTR quantities are sometimes overstated (62). Because D041 projections are inaccurate (32), too many of some parts are bought (19), which causes too few of some other parts to be bought (20). As a result, the right parts are not bought or repaired (24), and the backshops are sometimes unable to meet customer due dates (25). Consequently, MICAP support for customers in the field is impaired (26), causing aircraft at field units to be grounded (28) and the TI

backshops to lose customers (27). Lost customers (27) mean less workload for TI and WR-ALC (29) and a decrease in throughput for the depot (30). Furthermore, because engineering changes and weapon system phaseouts occur (21) and too many of some parts are bought (19), some finished goods end up as inapplicable inventory (22). As a result, overall inventory increases (15) and carrying costs increase (23), which increases overall operating expenses (16).

The fourth core constraint is restrictive personnel policies (35). These policies, along with the AFLC hiring and promotion freezes (36) and the RIFs and early outs (43), have led to shortages in some critical skills (37), causing the pool of workers qualified to perform some critical tasks to shrink (38). The shrinking pool of qualified workers (38) leads to resource contention problems (39), which sometimes cause personnel not to be available to complete critical steps (63). Consequently, aircraft flow days are longer than expected (40). As a result, AMREP due dates are adjusted back (41), and C-130s remain in depot longer than anticipated (42), causing throughput to decline (30) and aircraft depot inventory to increase (15). Future throughput also declines due to WR-ALC's lack of updated technology (61), a problem that has its roots in the traditional cost accounting methods used to justify investments (55). Use of these methods (55) results in poor investment decisions (56). If the wrong investment decisions are made (56), then the wrong technology is bought

(57). Consequently, money may not be available to buy the right technology (60), resulting in a lack of updated technology (61). In addition, defense budget reductions (54) have led to reductions in funding for equipment and technology (58). Thus, less money is available to upgrade equipment and technology (59), which results in a lack of funding (60) and a lack of updated technology (61).

The fifth core constraint, restrictive public contract laws (44), forces WR-ALC to consider all vendors and to make concessions to small businesses (45). As a result, more bid packages must be considered (47). In addition, WR-ALC is sometimes required to award contracts to small businesses, regardless of capability (46). Because WR-ALC must award contracts to these businesses (46) and because small business prices are sometimes higher (48), WR-ALC's ability to compete on price is limited (52), and WR-ALC loses customers (53). Of course, lost customers (53) cause the ALC workload to decrease (29) and throughput to drop (30). Because more bid packages must be considered (47), the time required to award contracts is longer than necessary (49). Therefore, it takes longer to obtain parts (50), and WR-ALC's ability to compete on due date performance is impaired (51). Consequently, WR-ALC's backshops are sometimes unable to meet customer due dates (25). Inability to meet customer due dates eventually leads to a decline in depot throughput (30).

Revising contracting laws (44) and budget policies (17) and using forward-looking, rather than backward-looking, data systems (31) could certainly help alleviate parts availability problems. Greater flexibility in personnel assignment policies (35) would also help remedy shortages in some critical skills. Unfortunately, the four core problems shown on the right-hand side of Figure V-8 (17, 31, 35, 44) represent AFLC and DOD policies which depot-level managers have little power to change. However, revision of organizational and individual performance criteria (1) is within the control of WR-ALC managers and is being encouraged by the WR-ALC center commander. If the changes currently being implemented at the directorate and center levels at WR-ALC are to succeed, the efficiency measures used to evaluate first-line maintenance supervisors and the program execution criteria used to measure item manager performance must be eliminated. Therefore, because incongruencies in performance measurement systems (1) can be corrected by managers at depot level, this researcher believes that this core problem constitutes the biggest barrier to C-130 mission accomplishment.

C-141 Depot Maintenance

AFLC Goals and Depot Objectives

Figure V-10 shows the numerical ratings given by the C-141, TI, and LY directorate and division chiefs on the congruency between AFLC goals and depot objectives. Based on the large p-value associated with the Mann-Whitney U test

Numerical Ratings

Unit	Directorate	Division
C-141	4	3
LY	4	4
TI	3	3
Average	3.67	3.33

Mann-Whitney U Test

Function	Rank Sum	Sample Size	U Stat	Average Rank
Aircraft	7.00	2	4.000	3.5
Support	14.00	4	4.000	3.5
Total	21.00	6		

Two-Tailed P Value for Normal Approximation .8170

Figure V-10. C-141 Numerical Ratings and Mann-Whitney U Test for Congruency of AFLC Goals and Depot Objectives

(see Figure V-10), it was concluded that no significant differences existed between the rankings of the congruency of AFLC goals and depot objectives at the .01 and .05 levels of significance for these two groups of managers. The average rank of 3.5 for each group indicates that these individuals believe that their command, center, and directorate goals and objectives support each other to a fairly high degree.

The tabular comparison and bullet summaries of directorate goals provided in Figure V-11 tend to support the beliefs of survey respondents. The WR-ALC and LY goals closely parallel each other and are extracted from the single goal/mission statements developed by each of these organizations. Though the C-141 goals do not appear to resemble those of the center and the other two directorates, the sixteen specific objectives related to these goals strongly support the WR-ALC goals. The objectives for depot maintenance, directly address improved customer delivery, cost reduction, inventory reduction, and PDM flow day reduction.

Competitive Edges

Managers at four levels - directorate, division, branch, and first-line supervision - were asked to rank the importance of the competitive edges of cost, quality, lead time, delivery, product/process flexibility, and product/process innovation for accomplishing C-141 depot maintenance. One set of rankings was based upon unit

Comparison of Goals/Objectives Across Organizations

Goals/Objectives	AFLC	WR-ALC	C-141	Avionics	TI
Profitability		X	X	X	X
Quality	X	X	X	X	X
Timeliness (Delivery)		X	X	X	X
Customer Satisfaction	X	X	X	X	X
Process Improvement			X		

X = Organization has a goal/objective pertaining to goal/objective listed in the right-hand column

Summary of WR-ALC and C-141, LY, and TI Goals

WR-ALC Goals

Operate Profitably

Provide On-time Delivery

Provide Quality Products

Ensure Wartime Capability

Avionics Goals

Customer Support

On-time Delivery

Quality Products

Make a Profit

C-141 Goals

Deploy Active TQM Program

Exceed Customer Expectations for Depot Maintenance

Exceed Customer Expectations for Materiel Support

Provide Best in Class Technical Services

TI Goals

Reduce Production Cost

Ensure Customer Satisfaction

Increase OPMD

Decrease F-15 Wing Flow Days

Assure Quality Products

Streamline Engineering

No Hazardous Waste Violations

Figure V-11. Comparison of WR-ALC and Directorate Goals

objectives, while the other set was based on the criteria, or management indicators, used to report unit performance. To determine whether significant differences existed between the mean rankings of the competitive edges themselves, Friedman Two-Way Analysis of Variance of Ranks tests were conducted on the two sets of rankings. In addition, median tests were used to determine whether differences existed between higher-level (directorate and division chiefs) and lower-level (branch chiefs and first-line supervisors) C-141, LY, and TI managers on the rankings of individual competitive edges. Median tests were also used to ascertain whether differences existed between all levels of aircraft (C-141) managers and all levels of managers from supporting directorates (LY and TI) on individual competitive edge rankings.

Based on the two organizational levels, no significant differences existed between the ranks of the competitive edges at the .01 and .05 levels of significance. On the basis of function, though, for both the objectives and criteria sets of rankings, differences did exist at the .01 and .05 levels of significance. This conclusion was based on the large chi square and small p-values associated with the two median tests shown in Figure V-12. On the basis of both objectives and criteria, C-141 support managers definitely regarded flexibility to be more important than did C-141 aircraft managers. This difference might stem from the fact that, until very recently, the C-141 depot

Median Test for Flexibility = Function			
	Function		
	Aircraft	Support	Total
Above Median	6	0	6
Below Medan	1	4	5
Total	7	4	11
Ties with Median	1	4	5
Median Value			5.000
Chi-Square			7.54
P-Value			0.0060
Degrees of Freedom			1

Median Test for Flexibility = Function			
	Function		
	Aircraft	Support	Total
Above Median	6	1	7
Below Medan	1	4	5
Total	7	5	12
Ties with Median	1	3	4
Median Value			5.000
Chi-Square			5.18
P-Value			0.0228
Degrees of Freedom			1

Figure V-12. Median Test Results for C-141 Depot Maintenance Competitive Edge Rankings by Objectives and by Function (top) and by Criteria and by Function (bottom)

maintenance workload has been quite stable and predictable. Thus, C-141 managers would tend to place little importance on flexibility.

However, the Friedman tests revealed that, on the basis of both objectives and criteria, significant differences existed between the mean ranks of the competitive edges themselves at the .01 and .05 levels of significance. This conclusion was based on the small p-values associated with the competitive edges factor (see Figure V-13). The Bonferroni Pairwise Comparison procedure was used to analyze each pair of competitive edge means and determine where these differences existed. A family significance level of .20 was selected for the analysis. The results of the pairwise comparisons are illustrated in Figure V-14.

On the basis of performance criteria, quality, cost, and delivery are deemed to be the three most critical competitive edges. Innovation and flexibility are considered to be the least important edges. While the ranking for lead time is not significantly different from the rankings for innovation and flexibility, it is high enough so that it is not significantly different from delivery either. Thus, lead time may be regarded as neither critical nor unimportant. On the basis of unit objectives, quality is definitely considered to be the most critical competitive edge, while flexibility is ranked as the least important edge. The rankings of the other four edges, though, are so close together that they are not

Friedman Two-Way Nonparametric Analysis of Ranks		
Competitive Edges	Mean Rank	Sample Size
Cost	3.38	16
Delivery	2.81	16
Flexibility	4.94	16
Innovation	4.31	16
Lead Time	3.50	16
Quality	2.06	16
Friedman Statistic		24.14
P-Value, Chi-Squared Approximation		0.0002
Degrees of Freedom		5

Friedman Two-Way Nonparametric Analycis of Ranks		
Competitive Edges	Mean Rank	Sample Size
Cost	2.44	16
Delivery	2.75	16
Flexibility	5.00	16
Innovation	4.63	16
Lead Time	4.00	16
Quality	2.19	16
Friedman Statistic		32.82
P-Value, Chi-Squared Approximation		0.0000
Degrees of Freedom		5

Figure V-13. Friedman Two-Way Analysis of Variance of Ranks Results: C-141 Depot Maintenance Competitive Edge Rankings by Objectives (top) and by Criteria (bottom)

C-141 Pairwise Comparison of
Competitive Edge Means by Objectives

Quality	Delivery	Cost	Lead Time	Innovation	Flexibility
2.06	2.81	3.38	3.50	4.31	4.94

NOTE: Means which are underlined are not significantly different

C-141 Pairwise Comparison of
Competitive Edge Means by Objectives

Quality	Cost	Delivery	Lead Time	Innovation	Flexibility
2.19	2.44	2.75	4.00	4.63	5.00

NOTE: Means which are underlined are not significantly different

Figure V-14. Bonferroni Pairwise Comparison Results

significantly different. Based on the actual numerical data, however, it could probably be concluded that most managers considered delivery to be the second most important objective/edge and regarded innovation as the second least important competitive edge (on the basis of unit objectives).

Performance Criteria

A number of the DDPMS performance criteria, as well as those employed by WR-ALC organizations, are aggregated cost-based or efficiency-related ratios. Nonetheless, supervisors at all levels at WR-ALC tend to believe that their performance criteria support AFLC goals and depot objectives to a significant degree. Only three individuals, the TI director, one LY first-line supervisor, and one C-141 production branch chief, rated the congruency between performance criteria and depot objectives as slight. Managers at four levels - directorate, division, branch, and first-line supervision - were asked to rate the extent to which they believed their organization's management indicators supported their depot and directorate objectives and command goals. The actual ratings of directors and division chiefs and the average ratings of branch chiefs and first-line supervisors are reported in Figure V-15. Mann-Whitney U tests were conducted on the survey results to determine whether significant differences existed between the mean rankings of the managers at the four different levels. The results of these tests, shown in Figure V-16,

Congruency of Performance Criteria and Depot Objectives				
Level/Org	Directorate	Division	Branch	First-Line
C-141	3	3	3.00	3.83
LY	3	4	3.25	3.00
TI	2	4	3.50	3.00

Figure V-15. C-141 Depot Maintenance Ratings for Congruency of Performance Criteria and Depot Objectives by Organizational Levels

Directorate -vs- Division Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Directorate	7.50	3	1.500	2.5
Division	13.50	3	7.500	4.5
Total	21.00	6		
Two-Tailed P-Value for Normal Approximation				0.2752

Directorate -vs- Branch Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Directorate	21.00	3	15.00	7.0
Branch	99.00	12	21.00	8.3
Total	120.00	15		
Two-Tailed P-Value for Normal Approximation				0.7182

Directorate -vs- First-Line Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Directorate	16.50	3	10.50	5.5
First-Line	103.50	12	25.50	8.6
Total	120.00	15		
Two-Tailed P-Value for Normal Approximation				0.3123

Figure V-16. Mann-Whitney U Test Results for Congruency of Performance Criteria and Depot Objectives by Organizational Levels

Division -vs- Branch Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Division	32.00	3	26.00	10.7
Branch	88.00	12	10.00	7.3
Total	120.00	15		
Two-Tailed P-Value for Normal Approximation				0.2790

Division -vs- First-Line Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Division	27.50	3	21.50	9.2
First-Line	92.50	12	14.50	7.7
Total	120.00	15		
Two-Tailed P-Value for Normal Approximation				0.6650

Branch -vs- First-Line Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Branch	133.50	12	55.50	11.1
First-Line	166.50	12	88.50	13.9
Total	300.00	24		
Two-Tailed P-Value for Normal Approximation				0.3556

Figure V-16. Mann-Whitney U Test Results for Congruency of Performance Criteria and Depot Objectives by Organizational Levels (Cont'd)

indicate that, at the .01 and .05 significance levels, no significant differences existed between the mean rankings of each of the four groups of managers. This conclusion was based on the large p-values associated with each test (i.e., accept Ho). On the basis of p-values, the directorate versus branch and division versus first-line rankings appear to display the greatest agreement. Conversely, the division versus branch and directorate versus division rankings seem to exhibit more dissimilarity. Although these findings are somewhat contrary to what might be expected, they are consistent with the data given in Figure V-15.

The contents of the C-141, LY, and TI monthly management reviews parallel the goals and objectives of these organizations. The presentation format for these reviews consists of bar graphs or pie charts, enabling those viewing the briefing to easily detect discrepancies and observe trends. In many categories, particularly financial management, the data is presented for each month in the current fiscal year as well as on a cumulative year-to-date basis. In some cases, as for TI material, operating, and G&A expenses, information pertaining to the previous fiscal year is also shown. As a result, expenses for the same months can be compared at a glance. The addition to the TI review of the slides on COD funds and MIC inventory should allow the directorate to better monitor the money it has tied up in bench stock and is spending for TDY travel and overtime. The TI review also has a stronger customer

orientation than before. The new slide on customer reported deficiencies is especially noteworthy because it represents an attempt to track all customer-reported defects and not just those reported through QDR channels. Given the volume of information presented in the TI Management Review, the directorate might consider splitting the briefing into internal and external versions, like the C-141 directorate has done.

The internal C-141 Management Review gives the C-141 director visibility over materiel and technical support problems and details about many categories of operating expenses for the current month. Fiscal trend information is presented in the net profit portion of both the internal and external reviews. However, the center commander sees only the aggregated information on cost and revenue shown in the external review and is not burdened with operating expense details. Compared to the internal review, the external briefing spends more time on the two management areas presently categorized in red (poor) status - depot maintenance and manpower and personnel. This concentration is logical, considering that the WR-ALC commander has directed that management reviews be structured to focus on problem areas.

The high percentage of the Avionics Management Review devoted to contracting status (50 percent) may partially be explained by the fact that, in the short term, contracting actions are probably more critical to depot exchangeables

repair than to aircraft depot maintenance. Both the C-141 and avionics reviews concentrate on examining various actions and processing times that directly impact their throughput. The briefings virtually ignore such previous management indicators as OPMD and direct labor effectiveness. Of course, several branch chiefs and first-line supervisors surveyed listed effectiveness as an important indicator of unit performance. Although many lower-level managers have not yet embraced the new performance criteria, it is obvious that a number of directors at WR-ALC have changed their thinking on management indicators. Hence, there probably is some justification to the rankings given by WR-ALC managers on the congruency of performance criteria and depot objectives.

System Constraints

The diagram in Figure V-17 shows the impact of various constraints on C-141 depot maintenance performance. The numbers in parentheses in this section refer to the numbered blocks in Figure V-17. Throughput (T), inventory (I), and operating expense (OE) are the three criteria used to measure C-141 depot maintenance performance. Reductions in T and increases in I and OE can be traced to the following core constraints: lack of systematic project management procedures for planning C-141 aircraft repair (1), data from the G019 and D041 systems that does not reflect current demand (20), lack of reporting scrap and rework (40), training programs receiving a low priority (48), and

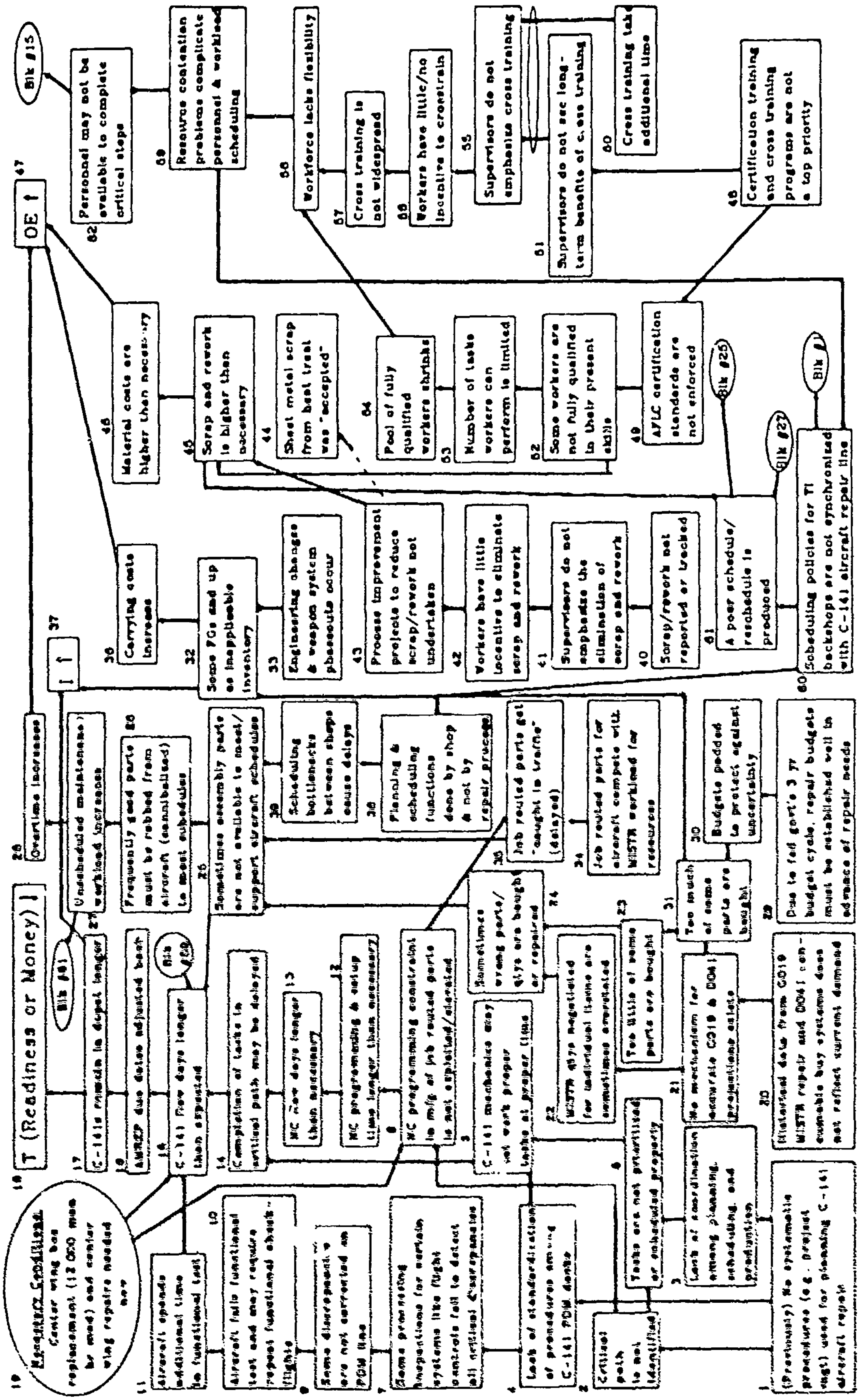


Figure V-17. ECE Diagram for C-141 Depot Maintenance

traditional scheduling policies (60). Of course, the necessary conditions listed in Figure V-9 and the personnel and contracting policy constraints and undesirable effects emanating from defense budget reductions that are illustrated on the right-hand side of the C-130 diagram also apply to depot maintenance for C-141, F-4, F-16, A-10, and F-111 aircraft. However, the purpose of the diagram in Figure V-17 is to focus on the issues emphasized in this case.

Until recently the planning for C-141 PDM lacked a dynamic, systematic approach (1). Based on a plan developed in isolation months earlier, each aircraft was input to a particular branch on a specified date, regardless of whether the depot or the branch could accommodate the workload at the time of actual input. Because no systematic procedures were used for planning C-141 aircraft repair (1), a critical repair path was not identified (2), standardization of procedures among the C-141 PDM docks was lacking (4), and little coordination among the planning, scheduling, and production functions existed (3). With no identification of a critical path (2), tasks were not prioritized or scheduled properly (5), and steps (of elevation or exploitation) were not taken to eliminate the NC programming constraint (8). Lack of coordination among planning, scheduling, and production personnel (3) also resulted in improper task prioritization and scheduling (5), which led to C-141 mechanics not working on the proper tasks at the proper time

(6). Because mechanics were not always working the proper tasks (6), completion of tasks in the critical path was sometimes delayed (14), and C-141 flow days were longer than expected (15).

Due to the lack of standardization among the C-141 docks (4), the thoroughness of preprocessing inspections for various aircraft systems varied among the docks, which meant that for certain systems, like flight controls, not all critical discrepancies were detected (7). Consequently, some discrepancies were not corrected on the PDM line (9), and more aircraft failed functional test and required repeat functional check flights (FCFs) (10). Due to repeated FCF failures (10), C-141 aircraft spent more time than necessary, sometimes as long as 18 days, in functional test (11). As a result, C-141 flow days were longer than anticipated (15), causing AMREP due dates to be adjusted back (16), which in turn caused C-141s to remain in the depot longer than expected (17). More C-141s at WR-ALC for a longer period (17) led to a decline in system throughput (18) and an increase in aircraft depot inventory (37). (With the implementation of Timeline, better incoming inspections (7), and better coordination among planners, schedulers, and first-line production supervisors (3), the C-141 directorate is attempting to correct these problems.)

The necessary conditions block (19) refers to the workload increase levied on the directorate by the command. While the center wing box replacement was directed in 1988,

the center wing repair project only recently became necessary because of the growing frequency of wing crack problems in the aging C-141 fleet. Center wing repairs and the center wing box modification (19) have not only led to an increase in C-141 flow days (15) but have also caused a substantial increase in the workload for TI's NC machine shop, which has resulted in NC programming becoming a constraint for C-141 aircraft repair (8). Failure to elevate or exploit the NC programming constraint (8) has caused NC programming and setup time (12) and NC flow days (13) to be longer than necessary, which has delayed completion of tasks in the critical path (14). (To alleviate NC programming delays, TI is installing Computervision. Computervision will automate several NC programming tasks that previously took days to accomplish and will enable WR-ALC to process its own NC programs, rather than having to rely on OO-ALC.)

The second core constraint, the fact that G019 and D041 data does not reflect current demand (20), impacts parts procurement. Due to this problem (20), no mechanism for accurate G019 projections exists (21), so negotiated MISTR quantities are sometimes overstated (22). Also, without accurate D041 projections (21), too many of some parts are bought (31), causing some finished goods to end up as inapplicable inventory (32). Inapplicable inventory is also the result of engineering changes and weapon system phaseouts (33). Inapplicable inventory (32) causes overall

inventory to increase (37) and carrying costs to increase (36), which leads to higher operating expenses (47). In addition, because repair budgets must be established well in advance of repair needs (29) (third core problem), budgets are padded to protect against uncertainty (30), which means that too many of some parts are bought (31). Purchase of too many of some parts (31) results in too few of some other parts being bought (23). Overstated MISTR quantities (22) and too few of some purchased parts (23) cause the wrong parts or wrong quantities of parts to be repaired or bought (24), which results in assembly parts sometimes not being available to support aircraft repair schedules (25). Assembly parts include both MISTR parts and job routed parts. While the NC programming constraint (8) causes some job routed parts to be delayed (35), more often these parts are delayed because they must compete with the MISTR workload for resources (34). If job routed parts are delayed (35), then assembly parts are not always available to support aircraft schedules (25). Thus, C-141 flow days are longer than expected (15), and often good parts must be robbed from aircraft (26). Cannibalization (26) causes the unscheduled maintenance workload to increase (27), which leads to more overtime (28) and increased operating expenses (47).

The fourth core constraint, no reporting or tracking of scrap and rework (40), causes supervisors not to emphasize the elimination of scrap and rework (41), which results in

workers having little incentive to eliminate scrap and rework (42). As a result, process improvement projects to reduce scrap and rework are not undertaken (43), causing scrap and rework to be higher than necessary (45). Higher scrap and rework (45) not only necessitates changes in TI backshop schedules (61) but also causes material costs to be higher than necessary (46), which increases overall operating expenses (47). Lack of process improvement projects aimed at scrap and rework reduction (43) may be verified by the fact that sheet metal scrap from heat treat was long accepted as standard operating procedure (44). (Fortunately, the recent installation of an automated temperature monitoring system for TI's heat treating ovens has greatly reduced heat treat scrap.)

The fifth core constraint, certification training and cross training programs not being a top priority (48), results in AFLC certification standards not being enforced (49). Lax enforcement of certification standards (49) means that some workers are not fully qualified in their present skills (52), which limits the number of tasks that workers can perform (53). Because workers can perform only a limited number of tasks (53), the pool of fully qualified workers shrinks (54), which causes the workforce to lack flexibility (58). These problems (59) mean that personnel may not be available to complete critical steps (62). Consequently, C-141 flow days are longer than expected (15). Fewer qualified workers (54) also result in higher scrap and

rework (45). Because cross training is not a high priority (48), supervisors do not see the long-term benefits of cross training (51). Consequently, they do not emphasize it (55), and workers have little or no incentive to cross train (56). As a result, cross training is not widespread (57), and the workforce lacks flexibility (58), exacerbating resource contention problems (59). The fact that cross training takes additional time (50) <u>and</u> that supervisors do not see the benefits of cross training (51) also cause supervisors to emphasize it less.

The sixth core problem, the lack of synchronization between TI backshop scheduling and C-141 aircraft repair scheduling (60), is related to the remanufacturing environment that characterizes depot aircraft repair. Remanufacturing involves three distinct operations - disassembly, repair/remanufacturing, and reassembly (McHugh, 1988). Although researchers commonly discuss the need for disassembly bills of material and dynamic routings in a remanufacturing environment (Boyer, 1987; Ward, 1988), they do not address how to synchronize the disassembly and reassembly of many component parts with the disassembly and reassembly of the entire end item to which these parts belong. For depot-level aircraft repair, the last part that is removed from an aircraft is typically the first part that is reinstalled. In many cases when the parts that must be reinstalled first are unavailable, it is not possible to install other parts and the whole reassembly operation is

delayed. Although the PDM line assigns due dates to job routed items, generally no attempt is made to prioritize several items that may be due on the same day or to assign a higher priority to those parts critical for initial aircraft reassembly. Thus, the backshops work to meet due dates but may not always repair the right parts in the order that is most logical for aircraft reassembly. Of course, the fact that additional component failures may occur anytime prior to reassembly further complicates efforts to synchronize backshop and aircraft repair schedules.

This lack of synchronization (60) contributes to the lack of systematic procedures for C-141 aircraft repair (1) and also results in resource contention problems (59), the need to reschedule in the TI backshops (61), and the accomplishment of planning and scheduling by backshop, rather than by process (38). Because TI planning and scheduling is done by shop instead of by repair process (38), scheduling bottlenecks sometimes occur between shops and cause delays (39) that result in assembly parts not being available to support aircraft schedules (25). Poor schedules and reschedules (61) are also a result of the higher than necessary scrap and rework (45) and increases in unscheduled maintenance (27) and another reason that assembly parts are sometimes not available to meet aircraft schedules (25).

Although the six core constraints highlighted in Figure V-17 all hamper C-141 depot maintenance, many problems

related to planning C-141 repair are already being corrected. In addition, inventory reduction and biweekly MISTR repair programs would tend to obviate the need for accurate, long-range G019 MISTR repair and D041 consumable buy projections. Hence, managerial policies related to scheduling (60), defect reporting (40), and training (48) probably have the greatest long-term impact on C-141 depot maintenance performance. Improvements in scheduling and quality defect reporting and an emphasis on certification training and cross training are also needed at the other depot maintenance organizations (C-130, F-4, F-16, F-111, and A-10) examined in this study. Biweekly MISTR repair and increased coordination between aircraft schedulers and backshop schedulers would help synchronize repair schedules and improve system throughput. However, correction of quality management and training management deficiencies will require a major change in attitude among managers and workers alike. Because of the increased competition among depots within the AFLC and the DOD, the desire not to "look bad" is keener than ever. Thus, getting all depot maintenance organizations to honestly report quality defects, as well as other management indicators, will require a significant cultural change in the way the AFLC does business and monitors performance. An equally monumental task will be to convince first-line supervisors of the necessity of cross training. Nevertheless, a viable quality defect reporting system and a well-trained, flexible

workforce are essential if AFLC is to compete effectively with private industry.

F-4 Depot Maintenance

AFLC Goals and Depot Objectives

Figure V-18 shows the numerical rating given by the LA and LI directorate and division chiefs on the congruency between AFLC goals and depot objectives. The large p-value associated with the Mann-Whitney U test indicates that no significant differences existed between these rankings at the .01 and .05 levels of significance for these two groups of managers. The average rank of 3.2 for aircraft (LA) managers and 2.8 for support (LI) managers indicates that these individuals believe that their command, center, and directorate goals and objectives support each other fairly well but not as desired.

The LI goals are identical to the OO-ALC areas of focus -teamwork, customer satisfaction, continuous improvement, and being the supplier of choice. In turn, the four areas of focus correspond reasonably well to the AFLC goals of people, quality, and user support. However, the AFLC, OO-ALC, and LI goals are all so general that they tend to resemble vision statements rather than specific objectives on which the organizations can focus. Figure V-18 compares the topics covered by these three sets of goals and the goals of the aircraft directorate.

Numerical Ratings

Unit	Directorate	Division
LA	4	3, 4
LI	3	4
Average	3.50	3.67

Mann-Whitney U Test

Function	Rank Sum	Sample Size	U Stat	Average Rank
Aircraft	9.500	3	3.500	3.2
Support	5.500	2	2.500	2.8
Total	15.00	5		
Two-Tailed P Value for Normal Approximation				1.000

Comparison of Goals Across Organizations

Goals	AFLC	OO-ALC	LI	LA
People	X	X	X	X
Teamwork		X	X	X
Personal Accountability	X			
Quality/Continuous Improvement	X	X	X	X
Customer Satisfaction	X	X	X	X
Supplier of Choice		X	X	X

Figure V-18. F-4 Numerical Ratings and Mann-Whitney U Test for Congruency of AFLC Goals and Depot Objectives; Comparison of AFLC, OO-ALC, LI, and LA Goals

Competitive Edges

Managers at four levels - directorate, division, unit, and subunit - were asked to rank the importance of the competitive edges of cost, quality, lead time, delivery, product/process flexibility, and product/process innovation for accomplishing F-4 depot maintenance. One set of rankings was based upon unit objectives, while the other set was based on criteria, or management indicators, used to report unit performance. Friedman Two-Way Analysis of Variance of Ranks tests were conducted on the two sets of rankings to determine whether significant differences existed between the mean ranks of the competitive edges themselves. The tests revealed (see Figure V-19) that on the basis of both objectives and criteria, significant differences existed between the mean ranks of the competitive edges themselves at the .01 and .05 levels of significance. This conclusion was based on the small p-values associated with the competitive edges factor. The Bonferroni Pairwise Comparison results displayed in Figure V-20 highlight where the differences exist.

On the basis of unit objectives, quality and delivery are deemed to be the two most critical competitive edges. Innovation, lead time, and flexibility are considered to be the least important edges. It is not clear whether cost may be classified as a critical competitive edge. On the basis of performance criteria, quality, cost, and delivery are clearly considered to be more critical than lead time,

Friedman Two-Way Nonparametric Analysis of Ranks		
Competitive Edges	Mean Rank	Sample Size
Cost	3.31	16
Quality	1.38	16
Lead Time	4.50	16
Delivery	2.63	16
Flexibility	4.44	16
Innovation	4.75	16
Friedman Statistic		40.04
P-Value, Chi-Squared Approximation		0.0000
Degrees of Freedom		5

Friedman Two-Way Nonparametric Analysis of Ranks		
Competitive Edges	Mean Rank	Sample Size
Cost	2.44	16
Quality	1.50	16
Lead Time	4.50	16
Delivery	2.63	16
Flexibility	5.00	16
Innovation	4.94	16
Friedman Statistic		51.25
P-Value, Chi-Squared Approximation		0.0000
Degrees of Freedom		5

<u>Figure V-19</u>. Friedman Two-Way Analysis of Variance of Ranks Results: F-4 Depot Maintenance Competitive Edge Rankings by Objectives (top) and by Criteria (bottom)

F-4 Pairwise Comparison of Competitive Edge Means by Objectives

Quality	Delivery	Cost	Flexibility	Lead Time	Innovation
1.39	2.63	3.31	4.44	4.50	4.75

NOTE: Means which are underlined are not significantly different

F-4 Pairwise Comparison of Competitive Edge Means by Objectives

Quality	Cost	Delivery	Lead Time	Innovation	Flexibility
1.50	2.44	2.63	4.50	4.94	5.00

NOTE: Means which are underlined are not significantly different

Figure V-20. Bonferroni Pairwise Comparison Results

flexibility, and innovation. These differences between the two sets of Bonferroni comparisons are consistent with the information obtained in interviews and the performance criteria used by the divisions and units examined in this case. For example, on the basis of objectives, cost was ranked as neither critical nor unimportant. By criteria, though, cost ranked closely behind quality as the most important competitive edge.

Using the median test, the survey results were analyzed to determine whether differences existed between higher-level (directorate, division, and unit chiefs) and lower-level (subunit chiefs) LA and LI managers on the rankings of individual competitive edges. Because of how the reorganization was accomplished by OO-ALC, OO-ALC unit chiefs have a broader span of control than do branch chiefs at WR-ALC and SM-ALC. Hence, their rankings are included in the first group. Based on these two organizational levels, no significant differences existed between the ranks of the competitive edges at the .01 and .05 levels of significance. Though, on the basis of criteria, the differences between cost at the two levels are not significant, the chi square and p-values in Figure V-21 indicate that there is some disparity between the two levels on the importance of cost as a criterion.

Median tests were also used to ascertain whether differences existed between all levels of aircraft (LA) managers and all levels of support (LI) managers on

Median Test for Delivery = Function			
	Function		
	Aircraft	Support	Total
Above Median	6	1	7
Below Medan	0	4	4
Total	6	5	11
Ties with Median	3	2	5
Median Value			2.000
Chi-Square			7.54
P-Value			0.0060
Degrees of Freedom			1

Median Test for Delivery = Function			
	Function		
	Aircraft	Support	Total
Above Median	3	4	7
Below Medan	4	0	4
Total	7	4	11
Ties with Median	2	3	5
Median Value			2.000
Chi-Square			3.59
P-Value			0.0581
Degrees of Freedom			1

Figure V-21. Median Test Results for F-4 Depot Maintenance Competitive Edge Rankings by Objectives and by Function (top) and by Criteria and by Organizational Level (bottom)

individual competitive edge rankings. In this case, on the basis of performance criteria, there were no significant differences at either the .01 or .05 levels of significance. On the basis of unit objectives, though, differences did exist at the .01 and .05 significance levels. This conclusion was based on the large chi square and small p-values associated with the median test shown at the top of Figure V-21. Thus, although LA managers considered delivery to be a critical criterion, they did not regard it to be as important an objective as did the LI managers.

Performance Criteria

Managers at the directorate, division, unit, and subunit levels were asked to rate the extent to which they believed their organization's management indicators supported their depot and directorate objectives and command goals. The actual ratings of directors and division chiefs and the average ratings of unit and subunit chiefs are reported in Figure V-22. Only the landing gear division chief recognized a disconnect between his organization's performance criteria and objectives. All other supervisors rated the congruency between performance criteria and depot objectives as significant or great. Mann-Whitney U tests were conducted on the survey results to determine whether significant differences existed between the mean rankings of the managers at the four different levels. The results of these tests, shown in Figure V-23, indicate that, at the .01 and .05 significance levels, no significant differences

Congruency of Performance Criteria and Depot Objectives				
Level/Org	Directorate	Division	Unit	Subunit
LA	4	3.50	3.67	3.00
LI	4	2	3.00	3.50

Figure V-22. F-4 Managers' Ratings for the Congruency of Performance Criteria and Depot Objectives

Directorate -vs- Division Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Directorate	8.00	2	5.000	4.0
Division	7.00	3	1.000	2.3
Total	15.00	5		
Two-Tailed P-Value for Normal Approximation				0.3865

Directorate -vs- Unit Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Directorate	9.00	2	6.00	4.5
Unit	12.00	4	2.00	3.0
Total	21.00	6		
Two-Tailed P-Value for Normal Approximation				0.4875

Directorate -vs- Subunit Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Directorate	14.00	2	0.00	7.0
Subunit	31.00	7	3.00	4.4
Total	45.00	9		
Two-Tailed P-Value for Normal Approximation				0.3055

Figure V-23. Mann-Whitney U Test Results for Congruency of Performance Criteria and Depot Objectives by Organizational Levels

Division -vs- Unit Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Division	10.00	3	4.00	3.3
Unit	18.00	4	8.00	4.5
Total	28.00	7		
Two-Tailed P-Value for Normal Approximation				0.5959

Division -vs- Subunit Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Division	13.50	3	7.50	4.5
Subunit	41.50	7	13.50	5.9
Total	55.00	10		
Two-Tailed P-Value for Normal Approximation				0.5688

Unit -vs- Subunit Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Unit	25.00	4	15.00	6.3
Subunit	41.00	7	13.00	5.9
Total	66.00	11		
Two-Tailed P-Value for Normal Approximation				0.9247

Figure V-23. Mann-Whitney U Test Results for Congruency of Performance Criteria and Depot Objectives by Organizational Levels (Cont'd)

existed between the mean rankings of each of the four groups of managers. This conclusion was based on the large p-values associated with each test. On the basis of p-values, the directorate versus division rankings display the least agreement, while the agreement of the unit versus subunit rankings is especially high.

The F-4 production unit and LI directorate management indicators parallel these organizations' goals. The goals and objectives of the aircraft operations division center around competition, quality, process improvement, and workforce training and team building. Three of the eight F-4 indicators are concerned with quality. The remaining indicators address training, workforce motivation (sick leave), and competition (production flow, overtime, and JON [Job Order Number] analysis). AFLC supervisors tend to give little attention to training. Thus, it is noteworthy that training is being regularly reviewed by aircraft division chiefs and directors.

Each of the LI management indicators is intended to measure one or more of the directorate's four focus areas. The MISTR workload, profit and loss, critical item status, and TQM environment indicators seem quite meaningful and relevant. On the other hand, the OPMD, funding execution, and manpower criteria typify the grossly aggregated measures traditionally used by AFLC. None of these criteria indicates whether the right items have been produced, whether funds have been obligated on the correct programs,

or which particular job skills have shortfalls. To those of the efficiency mindset, OPMD is probably an acceptable measure of continuous improvement. However, in this researcher's opinion, other criteria related to quality and delivery would seem to be much better indicators of continuous improvement.

By contrast, the landing gear division product line review charts go into great detail analyzing the causes of material supportability problems, identifying the supply source responsible and the weapon systems affected, and outlining the specific end items that are having production and parts problems. While the division monitors production on a very regular and detailed basis, not much attention seems to be devoted to reviewing engineering performance or financial status on a formal basis. For instance, none of the briefings reviewed contained information on AFLC 103 engineering changes, first article approvals, or DMIF profit and loss. The division may hold regular profit and loss reviews similar to those conducted in LI's technical repair center division, but this researcher was not informed that such was the case. With the advent of competition, it is likely that engineering and financial performance will be scrutinized more closely by the landing gear division.

System Constraints

The primary constraints in LI, and LIL in particular, revolve around material supportability. Increased personal accountability and cross training, including establishment

of the materiel and technical manager positions, would improve parts availability. Establishing these positions would drastically reduce the number of job classifications involved in the planning, scheduling, and materiel support tasks. In addition, the resultant larger pool of workers possessing a broader skills base would make it easier to absorb the impact of RIFs and handle workload fluctuations.

Uncertainty regarding future workload causes major difficulties in long-term planning and short-term scheduling for F-4 depot maintenance. However, at the worker level this uncertainty translates into morale problems and fears about job security. In nearly all cases job slots will not be lost but simply transferred to the F-16 and C-130 production units. Nonetheless, these transfers still cause some anxiety among personnel and a substantial loss in productivity while personnel are becoming proficient on a new weapon system. In addition, due to contract engineering data on wheels and brakes being proprietary, LIL spends more money than necessary on engineering changes, which hampers its ability to compete on price. Because OO-ALC's aircraft and commodities directorates support both the F-4 and F-16 aircraft, the constraints mentioned in this case are incorporated with those related to F-16 depot maintenance in a single ECE diagram included at the end of the F-16 case.

F-16 Depot Maintenance

AFLC Goals and Depot Objectives

The numerical ratings and Mann-Whitney U test results for the congruency between AFLC goals and depot objectives are identical to those for the F-4 case (refer to Figure V-18). The chart in Figure V-24 shows the relationship between LA's goals and those of its LAO and LAR divisions. It is evident that the center's areas of focus parallel the command goals and that the goals of OO-ALC, LA, LAO, and LAR are closely intertwined. Although the directorate goals are quite broad, their wording is exceptionally strong. "True living master plan" and "MODEL directorate" stand out as being the most lofty goals. Nonetheless, developing competitive strategies and viable indicators are equally notable and could be regarded as prerequisites to the first two goals. Formulating viable indicators is no easy task but is certainly essential for achieving all the other goals. While a number of the AFLC directors interviewed in this study recognized the importance of good performance criteria, LA at OO-ALC was the only directorate to formally specify management indicator development as one of its goals. Finally, "institutionalize TQM" not only implies training personnel in TQM but also changing their mindsets and having them employ TQM in their day-to-day jobs.

It would have been desirable for the LAO and LAR divisions to include specific targets in their objectives (i.e., keep F-16 aircraft in depot inventory to under 40

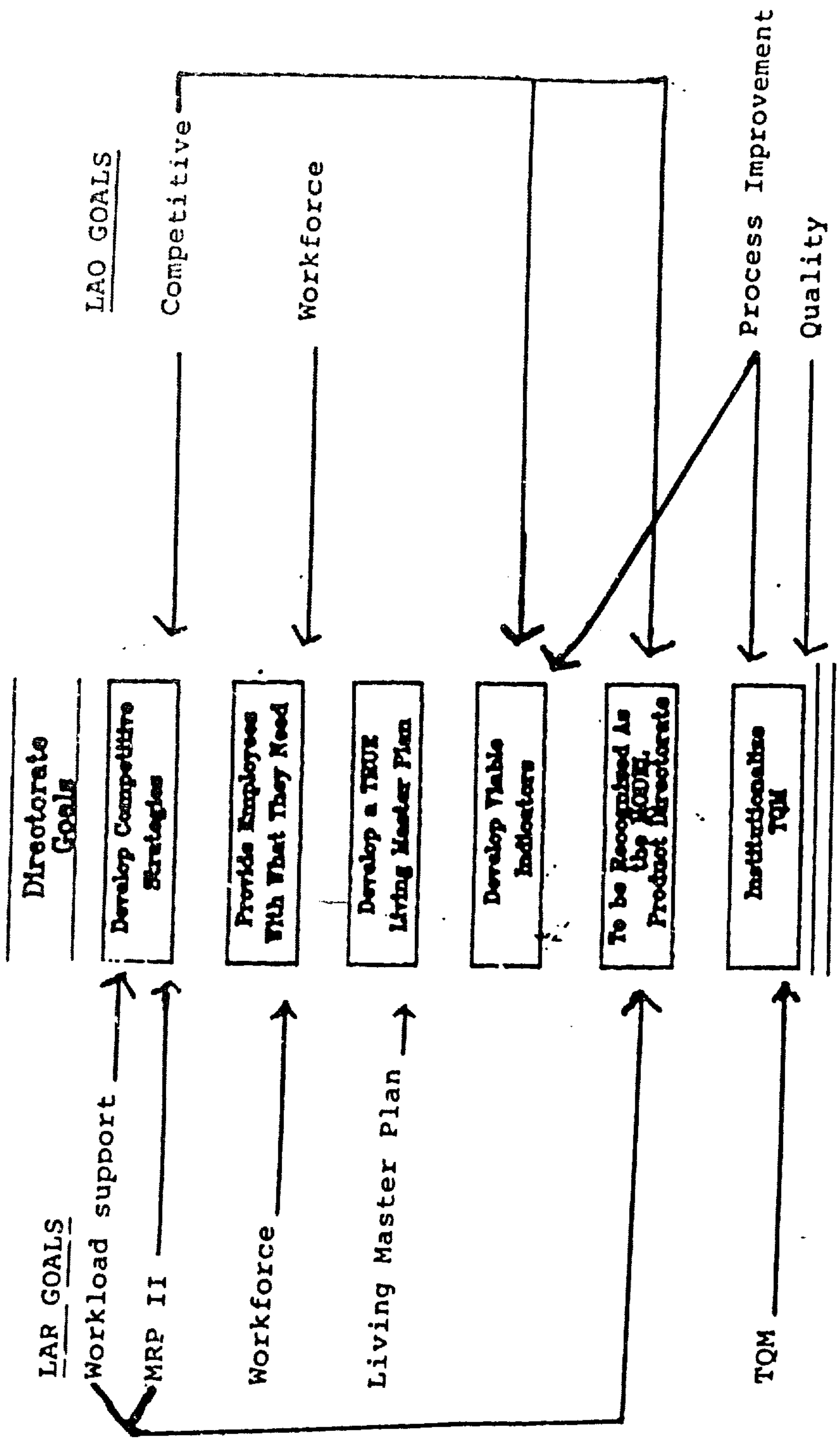


Figure V-24. Relationships Among LA, LAO, and LAR Goals

days). Nevertheless, the objectives that have been developed clarify and expand upon the goals so that the workforce can understand what the goals mean. The LAR objectives are probably too detailed for most shop floor workers, but they provide supervisors an excellent roadmap of what is expected of them. The goals on ensuring a fully supportable workload and developing a living master plan are especially noteworthy. The objectives related to these goals are detailed enough so that LAR personnel can understand what is meant by these goals and by the LA goals to which they are directly related.

Competitive Edges

Managers at the directorate, division, unit, and subunit levels were asked to rank the six competitive edges on the basis of unit objectives and of management indicators. Friedman Two-Way Analysis of Variance of Ranks tests showed that for each set of rankings, at the .01 and .05 levels of significance, significant differences existed between the mean ranks of the competitive edges themselves. This conclusion was based on the extremely small p-values present in both of the tests displayed in Figure V-25. The Bonferroni Pairwise Comparison test results shown in Figure V-26 highlight where the differences exist.

On the basis of unit objectives, F-16 managers clearly considered quality, delivery, and cost to be much more important than lead time, innovation, and flexibility. The rankings of the second and third most critical edges,

Friedman Two-Way Nonparametric Analysis of Ranks		
Competitive Edges	Mean Rank	Sample Size
Cost	2.81	16
Quality	1.63	16
Lead Time	4.41	16
Delivery	2.78	16
Flexibility	4.72	16
Innovation	4.66	16
Friedman Statistic		38.35
P-Value, Chi-Squared Approximation		0.0000
Degrees of Freedom		5

Friedman Two-Way Nonparametric Analysis of Ranks		
Competitive Edges	Mean Rank	Sample Size
Cost	2.75	16
Quality	1.63	16
Lead Time	3.00	16
Delivery	4.06	16
Flexibility	4.75	16
Innovation	4.81	16
Friedman Statistic		36.25
P-Value, Chi-Squared Approximation		0.0000
Degrees of Freedom		5

Figure V-25. Friedman Two-Way Analysis of Variance of Ranks Results: F-16 Depot Maintenance Competitive Edge Rankings by Objectives (top) and by Criteria (bottom)

F-16 Pairwise Comparison of Competitive Edge Means by Objectives

Quality	Delivery	Cost	Lead Time	Innovation	Flexibility
1.63	2.78	2.81	4.41	4.66	4.72

NOTE: Means which are underlined are not significantly different

F-16 Pairwise Comparison of Competitive Edge Means by Objectives

Quality	Cost	Delivery	Lead Time	Flexibility	Innovation
1.63	2.75	3.00	4.06	4.75	4.81

NOTE: Means which are underlined are not significantly different

Figure V-26. Bonferroni Pairwise Comparison Results

delivery and cost, are very close together and far ahead of that for lead time, the fourth-ranked edge. On the basis of performance criteria, the demarcation between the top three and bottom three competitive edges is not as distinct. Cost was ranked ahead of delivery and regarded as the second most important competitive edge. Delivery and lead time seem to be regarded as neither particularly critical nor completely unimportant. The Bonferroni comparison results are consistent with the management indicators that survey respondents listed as being the most important for evaluating their unit performance.

The survey results were also analyzed to ascertain whether differences existed between all levels of aircraft (LA) and support (LI) managers on the individual competitive edge rankings. Using median tests, on the basis of organizational function, no significant differences existed between the ranks of the competitive edges at the .01 and .05 levels of significance. Median tests were also used to determine whether differences existed between higher-level (directorate, division, and unit chiefs) and lower-level (subunit chiefs) LA and LI managers on the rankings of individual competitive edges. Although no significant differences were found at either the .01 or .05 significance levels, the chi square and p-values in Figure V-27 indicate that there was some disparity in the objectives category between the way higher-level and lower-level managers ranked delivery and flexibility.

Median Test for Delivery = Level			
	Level		
	Higher	Lower	Total
Above Median	6	2	8
Below Medan	3	5	8
Total	9	7	16
Ties with Median	0	0	0
Median Value			3.500
Chi-Square			2.29
P-Value			0.1306
Degrees of Freedom			1

Median Test for Flexibility = Level			
	Level		
	Higher	Lower	Total
Above Median	3	5	8
Below Medan	6	2	8
Total	9	7	16
Ties with Median	0	0	0
Median Value			5.500
Chi-Square			2.29
P-Value			0.1306
Degrees of Freedom			1

Figure V-27. Median Test Results for F-16 Depot Maintenance Competitive Edge Rankings by Objectives and by Organizational Level

Higher-level managers considered flexibility to be more critical than did lower-level managers. The subunit chiefs placed more importance on delivery. These ranking differences are quite logical, given the key job responsibilities of each of these groups of supervisors. Subunit chiefs are primarily held accountable for meeting due dates, while the higher-level managers have more responsibility for improving delivery performance. These managers realize that their organizations must be flexible in order to achieve all objectives, including those related to delivery.

Performance Criteria

Directorate, division, unit, and subunit chiefs rated the extent to which they believed their organizations' management indicators supported their depot and directorate objectives and command goals. The actual ratings of directors and division chiefs and the average ratings of unit and subunit chiefs are reported in Figure V-28. Mann-Whitney U test results (refer to Figure V-29) indicate that, at the .01 and .05 significance levels, no significant differences existed. This conclusion was based upon the large p-values associated with each test. The fact that the directorate versus division and unit versus subunit rankings display the highest agreement is totally consistent with the data given in Figure V-28.

Congruency of Performance Criteria and Depot Objectives				
Level/Org	Directorate	Division	Unit	Subunit
LA	4	3.50	3.33	3.25
LI	4	4	3.00	3.33

Figure V-28. F-16 Managers' Ratings for the Congruency of Performance Criteria and Depot Objectives

Directorate -vs- Division Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Directorate	7.00	2	4.000	3.5
Division	8.00	3	2.000	2.7
Total	15.00	5		
Two-Tailed P-Value for Normal Approximation				0.7728

Directorate -vs- Unit Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Directorate	10.00	2	7.00	5.0
Unit	11.00	4	1.00	2.8
Total	21.00	6		
Two-Tailed P-Value for Normal Approximation				0.2472

Directorate -vs- Subunit Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Directorate	15.00	2	12.00	7.5
Subunit	31000	7	2.00	4.3
Total	45.00	9		
Two-Tailed P-Value for Normal Approximation				0.1877

Figure V-29. Mann-Whitney U Test Results for Congruency of Performance Criteria and Depot Objectives by Organizational Levels

Division -vs- Unit Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Division	14.50	3	8.50	4.8
Unit	13.50	4	3.50	3.4
Total	28.00	7		
Two-Tailed P-Value for Normal Approximation				0.4795

Division -vs- Subunit Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Division	20.50	3	14.50	6.8
Subunit	34.50	7	6.50	4.9
Total	55.00	10		
Two-Tailed P-Value for Normal Approximation				0.4250

Unit -vs- Subunit Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Unit	23.50	4	13.50	5.9
Subunit	42.50	7	14.50	6.1
Total	66.00	11		
Two-Tailed P-Value for Normal Approximation				1.0000

Figure V-29. Mann-Whitney U Test Results for Congruency of Performance Criteria and Depot Objectives by Organizational Levels (Cont'd)

Although the addition of bar graphs to some LAO and LAR management review slides would enable those reviewing the data comprehend it more easily, the content of these reviews makes up for their lack of visual appeal. The LAO and LAR management review indicators emphasize quality, training, and production (output and delivery) and are directly correlated with division goals and objectives. While the production indicators included in these reviews are similar to those seen at other depot maintenance units, the attention that these reviews devote to training and quality is commendable. In the long run, training and quality have a considerable impact on throughput. AFLC maintenance organizations tend to ignore training, and AFLC management reviews typically address product quality with a single slide or criterion. The LAO and LAR reviews also exclude traditional, but less useful, indicators concerned with efficiency, program execution, and details on multiple categories of operating expenses. Examining profit and loss status in a separate meeting every week, instead of from a historical perspective once a month, obviates the need to include a multitude of operating expense data in the management reviews. Interestingly enough, though the LAO and LAR reviews ignore efficiency, LA is one of the few aircraft directorates in AFLC that is making money.

System Constraints

The ECE diagram in Figure V-30 shows the impact of various constraints on F-4 and F-16 depot maintenance

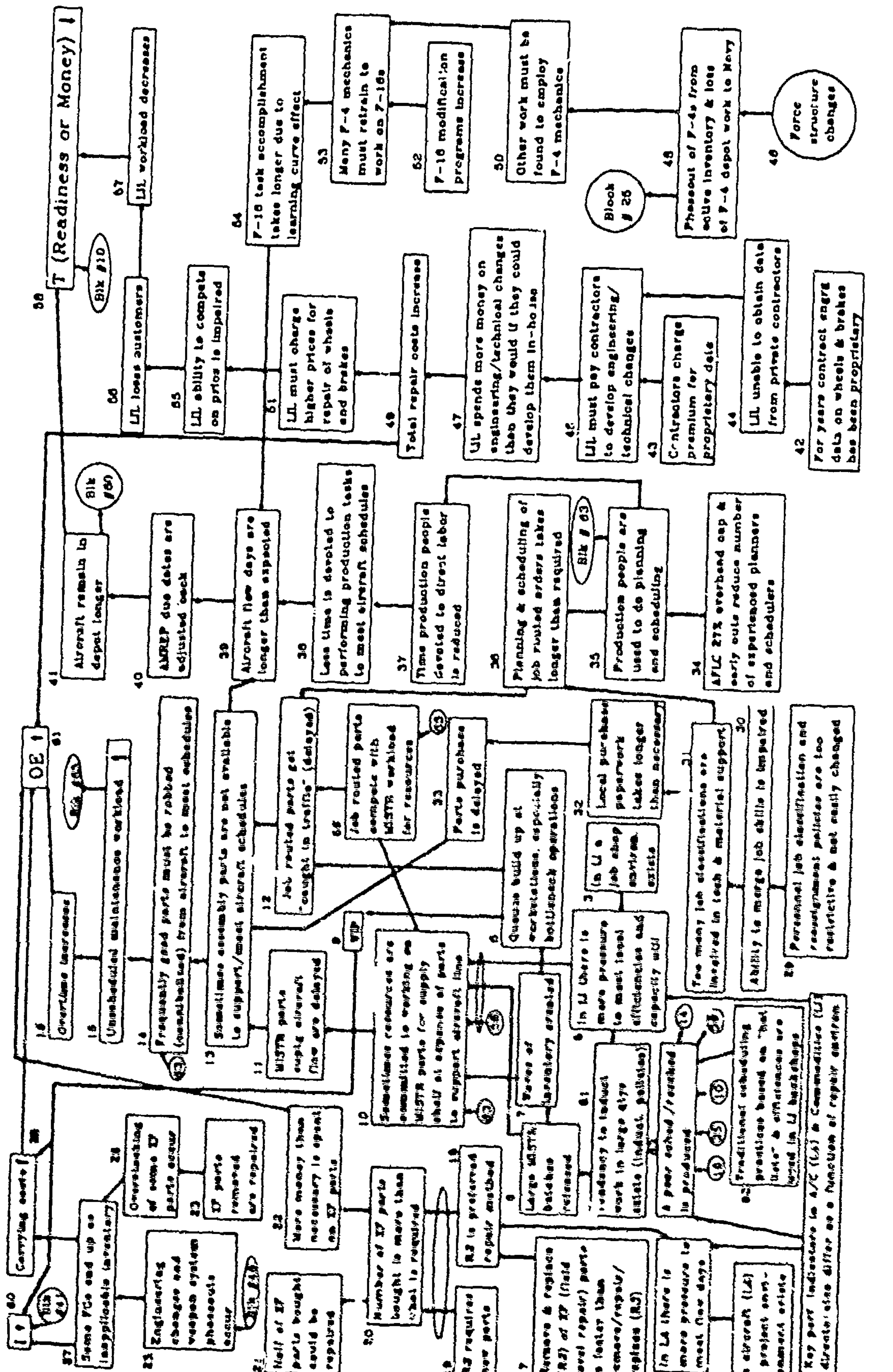


Figure V-30. ECE Diagram for F-4 and F-16 Depot Maintenance

performance. The numbers in parentheses in this section refer to the numbered blocks in F-16. Throughput (T), inventory (I), and operating expense (OE) are the three criteria used to measure C-141 depot maintenance performance. Reductions in T and increases in I and OE can be traced to the following core constraints: differences between the aircraft and commodities directorates regarding key performance indicators (1), restrictions in personnel job classification and reassignment policies (29), proprietary engineering data for wheels and brakes (42), and traditional scheduling practices (62). Events not under OO-ALC's or even AFLC's control, like Desert Storm and DOD force structure changes (46), also impact depot maintenance.

One of the most critical blocks on the diagram is that for the excessive number of job classifications involved in technical and material support (31). Currently, much overlap exists in the duties of planners, schedulers, materiel controllers, production management specialists, and equipment specialists. Because current personnel job classification and reassignment policies are very restrictive (29)(first core problem), the ability of depot managers to merge job skills is impaired (30). Consequently, paperwork must pass through too many hands within and between units (31), causing local purchase paperwork to take longer than necessary (32) and parts purchases to be delayed (33). Delays in purchased parts (33) sometimes cause assembly parts to be unavailable to

meet aircraft schedules (13). The excessive number of job classifications (31) also causes the planning and scheduling of job routed items to take longer than required (36), which delays the repair of these items (12). In turn, delays in job routed repair (12) cause assembly parts to be unavailable when needed (13). In addition, because the AFLC overhead cap and the early out offerings have reduced the number of experienced planners and schedulers (34), production personnel sometimes do planning and scheduling (35). As a result, these tasks take longer than required for job routed orders (36), and job routed parts get delayed (12). Using production people to perform planning and scheduling (35) reduces direct labor time for these individuals (37), which means that less time is devoted to performing production tasks to meet aircraft schedules (38), causing aircraft flow days to be longer than expected (39).

The LI backshop scheduling practices that are based on meeting efficiencies and using "hot lists" for dispatching (62) result in disconnects with aircraft repair schedules and constitute a second core constraint. While the need to link aircraft and backshop repair schedules was previously discussed in the C-141 case, this ECE diagram also points out the effects of poor schedules and rescheduling. Traditional scheduling practices (62) result in poor schedules and the need for rescheduling (63). Additional causes of poor schedules (63) are differences in performance indicators (1), the use of production employees to do

scheduling (35), and increases in the unscheduled maintenance workload for the aircraft repair line (15). The first cause (1) refers to LI's emphasis on meeting efficiencies, which conflicts with LA's need to meet aircraft flow days. One effect of poor schedules is an increase in parts cannibalization (14), which in turn increases unscheduled maintenance (15), making rescheduling necessary (63) and resulting in an ECE loop for aircraft repair. The second loop occurs in the backshops. Poor schedules cause backshop resources to be committed to repairing MISTR parts for supply at the expense of those for aircraft (10) and cause job routed items, which must compete with MISTR workload for resources, to receive inadequate attention (59). Thus, both MISTR parts (11) and job routed items (12) are delayed, causing assembly parts to be unavailable when needed (13) and cannibalization to be required (14). Cannibalization (14) increases unscheduled maintenance (15), which requires more overtime (16), thus increasing operating expenses (61).

The third core problem, differences in performance criteria (1), has a negative impact on inventory and operating expenses. Differences in key performance indicators (1) and the LA project management repair environment (2) mean that in LA more pressure exists to meet AMREP due dates by using as few manhours as possible (4). This pressure (4) causes removal and replacement of parts coded "XF" for field level repair to be the preferred repair

method for XF parts (18). This method is also preferred because it is faster than removal, repair, and replacement (17). Because removal and replacement requires new parts (19) and is the preferred method (18), more XF parts than necessary are bought (20), which means that more money than necessary is spent on XF parts (22), causing overall operating expenses to increase (61). OO-ALC managers estimate that half of the XF parts purchased could be repaired at the depot (21), which verifies the fact that too many XF parts are bought (20). In addition, because XF parts that are removed are repaired (24), overstocking of some XF parts occurs (26), causing some finished goods to end up as inapplicable inventory (27). Inapplicable inventory (27) raises overall inventory (60) and increases carrying costs (28), leading to higher operating expenses (61). Inapplicable inventory (27) also results from engineering changes and weapon system phaseouts (25).

By contrast, in commodities (LI) repair, a job shop environment exists (3), causing there to be more pressure in LI to meet efficiency and capacity utilization targets (5). Consequently, shops tend to induct large quantities of work (61), causing large MISTR batches to be released to the shop floor (6). These batches (6) create waves of inventory (7), causing queues to build up at workstations (8) and work-in-process inventory to increase (9), which increases inventory as a whole (60). Lengthy queues (8) also cause job routed items to be delayed (12), which results in assembly parts

not being available to meet aircraft schedules (13). In addition, pressure to meet local efficiencies (5), along with the release of large MISTR batches (6) and reductions in depot throughput (58), sometimes causes resources to be committed to working on MISTR parts for supply at the expense of parts for aircraft (10). Consequently, MISTR parts are delayed (11), causing assembly parts to be unavailable to support aircraft schedules (13). Due to lack of assembly parts (13), aircraft flow days are longer than expected (39). The final causes for miscommitment of backshop resources (10) stem from the huge waves of inventory (7) and the fact that job routed orders for aircraft compete with the MISTR workload for resources (59).

Force structure changes (46) also impact OO-ALC depot maintenance. One such change is the phaseout of F-4 aircraft from the active Air Force inventory and the transfer of the F-4 depot workload to the Navy (48). This decision (48) is an example of a weapon system phaseout (25) and means that other work must be found to employ F-4 mechanics (50). This fact (50) and the increase in F-16 modification programs (52) are causing LA to retrain many F-4 mechanics to work on F-16s (53). As a result, F-16 task accomplishment now takes longer due to the learning curve effect experienced by the F-4 mechanics (54). Consequently, F-16 aircraft flow days are sometimes longer than expected (39), causing AMREP dates to be adjusted back (40) and aircraft to remain in depot longer than expected (41). The

end results are a decline in depot throughput (58) and an increase aircraft depot inventory (60).

The fourth constraint, proprietary contract engineering data for aircraft wheels and brakes (42), is unique to OO-ALC but must be eliminated if this depot is to be competitive. Due to this core problem (42), the landing gear division (LIL) is unable to obtain data from private contractors (44). This inability (44) and the fact that contractors charge a premium for proprietary data (43) mean that LIL must pay contractors to develop engineering and technical changes (45). As a result, LIL spends more money on these changes than they would if they had the capability to develop them in-house (47). Thus, total wheel and brake repair costs increase (49), which leads to higher operating expenses (61). Repair cost increases (49) also cause LIL to charge higher prices for wheel and brake repair (51), which impairs LIL's ability to compete on price (55). Consequently, LIL loses customers (56), its workload decreases (57), and the depot's throughput decreases (58).

Although the problem with proprietary engineering data on wheels and brakes (42) is unique to OO-ALC, the other three core constraints in Figure V-30 also apply to the other depot maintenance organizations in this study. Equally applicable to the other organizations is the failure to repair XF parts. Even though the depots have the capability to repair these parts, their repair is not encouraged, causing inventories and operating expenses to be

unnecessarily high. By repairing XF parts, OO-ALC estimates that it could save $4 million annually. Assuming similar savings at AFLC's other four depots, an annual savings of $20 million for the command is not unrealistic. In this era of defense budget reductions and increased competition, this avenue for cost reduction certainly seems worth pursuing.

F-111 Depot Maintenance

AFLC Goals and Depot Objectives

Figure V-31 shows the numerical ratings and the Mann-Whitney U test results for the congruency between AFLC goals and depot objectives. The relatively large p-value associated with the Mann-Whitney U test indicates that no significant differences exist between the rankings of the aircraft (LA) and support (TI and LI) managers at the .01 and .05 levels of significance. Looking at the ratings and the average ranks, it can be seen that a majority of these managers believe that their command, center, and directorate goals and objectives support each other to a great extent.

From the chart in Figure V-31, it is evident that the SM-ALC and LA goals closely parallel each other. The center's training objective and the aircraft directorate's work environment goal correspond to AFLC's people goal. The fact that LA addresses AFLC's accountability goal in great detail is especially notable. Equally commendable are SM-ALC's and LA's performance measurement objectives. The center's first objective includes strategies for developing and baselining defect and cycle time measures. LA's

Numerical Ratings		
Unit	Directorate	Division
LA	4	3,3
LI	4	3
TI	4	4
Average	4.00	3.25

Mann-Whitney U Test				
Function	Rand Sum	Sample Size	U Stat	Average Rank
Aircraft	9.50	3	3.500	3.2
Support	18.50	4	8.500	3.3
Total	28.00	7		
Two-Tailed P-Value for Normal Approximation				0.4795

Comparison of Goals Across Organizations			
Goals	AFLC	SM-ALC	LA
People	X		X
Teamwork	X	X	
Personal Accountability	X		X
Quality	X		
Continuous Improvement		X	X
Customer Satisfaction/Support	X	X	X
Be Competitive		X	X
Performance Indicators/Measures		X	X

Figure V-31. F-111 Numerical Ratings and Mann-Whitney U Test Results for Congruency of AFLC Goals and Depot Objectives; Comparison of AFLC, SM-ALC, and LA Goals

customer satisfaction goal also includes objectives for defining and baselining customer satisfaction indicators. Finally, because the SM-ALC and LA goals and objectives explicitly address continuous improvement, this goal has been differentiated from quality in the comparison chart in Figure V-31.

Competitive Edges

Managers at the directorate, division, branch, and first-line supervision levels were asked to rank the six competitive edges on the basis of unit objectives and of management indicators. Friedman Two-Way Analysis of Variance of Ranks test results (see Figure V-32) showed that for each set of rankings, at the .01 and .05 levels of significance, significant differences existed between the mean ranks of the competitive edges themselves. This conclusion was based on the extremely small p-values associated with the competitive edges factor. The Bonferroni Pairwise Comparison results in Figure V-33 highlight where these differences exist.

On the basis of unit objectives, quality is clearly deemed to be the most important competitive edge. However, F-111 managers rank order of the other five edges was so varied that there is no significant difference among their means. Thus, it is impossible to draw any further conclusions. On the basis of performance criteria, quality, cost, and delivery are regarded as the most critical competitive edges. Innovation and flexibility are

Friedman Two-Way Nonparametric Analysis of Ranks		
Competitive Edges	Mean Rank	Sample Size
Cost	3.13	16
Quality	1.19	16
Lead Time	4.31	16
Delivery	3.25	16
Flexibility	4.50	16
Innovation	4.63	16
Friedman Statistic		38.75
P-Value, Chi-Squared Approximation		0.0000
Degrees of Freedom		5

Friedman Two-Way Nonparametric Analysis of Ranks		
Competitive Edges	Mean Rank	Sample Size
Cost	1.94	16
Quality	3.00	16
Lead Time	5.25	16
Delivery	4.63	16
Flexibility	4.44	16
Innovation	1.75	16
Friedman Statistic		50.11
P-Value, Chi-Squared Approximation		0.0000
Degrees of Freedom		5

Figure V-32. Friedman Two-Way Analysis of Variance of Ranks Results: F-111 Depot Maintenance Competitive Edge Rankings by Objectives (top) and by Criteria (bottom)

F-111 Pairwise Comparison of
Competitive Edge Means by Objectives

Quality	Cost	Delivery	Lead Time	Flexibility	Innovation
1.19	3.13	3.25	4.31	4.50	4.63

NOTE: Means which are underlined are not significantly different

F-111 Pairwise Comparison of
Competitive Edge Means by Objectives

Quality	Cost	Delivery	Lead Time	Innovation	Flexibility
1.75	1.94	3.00	4.44	4.63	5.25

NOTE: Means which are underlined are not significantly different

Figure V-33. Bonferroni Pairwise Comparison Results

considered to be unimportant. Lead time may be classified as neither critical nor unimportant. The differences between the two sets of Bonferroni comparisons are consistent with the data presented in Chapter IV. By objectives, all managers other than the NDI chief ranked quality as the most critical edge. On the basis of criteria, quality, cost, and delivery were ranked among the top three edges by all managers except LI's pneudraulics division chief.

Using the median test, the survey results were analyzed to determine whether differences existed between higher-level (directorate and division chiefs) and lower-level (branch chiefs and first-line supervisors) LA, LI, and TI managers on the rankings of individual competitive edges. Based on these two organizational levels, no significant differences existed between the ranks of the competitive edges at the .01 and .05 levels of significance. Median tests were also used to ascertain whether differences existed between all levels of aircraft (LA) managers and all levels of managers from supporting directorates (LI and TI) on individual competitive edge rankings. In this case, on the basis of management indicators, there were no significant differences at either the .01 or .05 levels of significance. On the basis of unit objectives, though, differences did exist at the .01 and .05 levels of significance. This conclusion was based on the large chi

square and small p-values associated with the two median tests shown in Figure V-34. F-111 support managers definitely did not regard innovation to be as important as did the aircraft managers. LA directorate and division chiefs believe that to successfully manage SM-ALC's ever-changing aircraft workloads, their directorate must be innovative. In addition, support managers regarded lead time to be more critical than did aircraft managers. This difference is understandable, considering how crucial component part lead time is for TI and LI MISTR repair.

Performance Criteria

Managers at directorate, division, branch, and first-line supervision levels rated the extent to which they believed their organizations' performance criteria supported their depot and directorate objectives and command goals. The actual ratings of TI and LI and the LA director and the average ratings of the aircraft division, branch, and first-line chiefs are reported in Figure V-35. Mann-Whitney U test results (refer to Figure V-36) show that, at the .05 significance level, significant differences existed between the ratings of branch chiefs and first-line supervisors. Although there were no other statistically significant differences, the small p-values for the directorate versus first-line and division versus first-line tests tend to indicate that, as a whole, first-line supervisors' ratings were considerably different from those of the other three

Median Test for Innovation = Function	Function		
	Aircraft	Support	Total
Above Median	1	7	8
Below Median	7	1	8
Total	8	8	16
Ties w/Median	0	0	0
Median Value			4.500
Chi-Square			9.000
P-Value			0.0027
Degrees of Freedom			1

Median Test for Lead Time = Function	Function		
	Aircraft	Support	Total
Above Median	5	2	7
Below Median	1	5	6
Total	6	7	13
Ties w/Median	2	1	3
Median Value			4.000
Chi-Square			3.900
P-Value			0.0483
Degrees of Freedom			1

Figure V-34. Median Test Results for F-111 Depot Maintenance Competitive Edge Rankings by Objectives and by Function (left) and by Criteria and by Function (right)

Congruency of Performance Criteria and Depot Objectives				
Level/Org	Directorate	Division	Unit	Subunit
LA	3	3	2.67	3.5
LI	3	3	3	4
TI	2	2	2	4

Figure V-35. F-111 Depot Maintenance Ratings for the Congruency of Performance Criteria and Depot Objectives by Organizational Levels

Directorate -vs- Division Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Directorate	11.50	3	5.500	3.8
Division	16.50	4	6.500	4.1
Total	28.00	7		
Two-Tailed P-Value for Normal Approximation				1.0000

Directorate -vs- Branch Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Directorate	14.00	3	8.000	4.7
Branch	22.00	5	7.000	4.4
Total	36.00	8		
Two-Tailed P-Value for Normal Approximation				1.0000

Directorate -vs- First-Line Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Directorate	7.00	3	1.000	2.3
First-Line	21.00	4	11.000	5.3
Total	28.00	7		
Two-Tailed P-Value for Normal Approximation				0.1116

Figure V-36. Mann-Whitney U Test Results for Congruency of Performance Criteria and Depot Objectives by Organizational Levels

Division -vs- Branch Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Division	21.50	4	11.50	5.4
Branch	23.50	5	8.50	4.7
Total	45.00	9		
Two-Tailed P-Value for Normal Approximation				0.8065

Division -vs- First-Line Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Division	11.50	4	1.500	2.9
First-Line	24.50	4	14.500	6.1
Total	36.00	8		
Two-Tailed P-Value for Normal Approximation				0.0833

Branch -vs- First-Line Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Branch	16.50	5	1.500	3.3
First-Line	28.50	4	18.500	7.1
Total	45.00	9		
Two-Tailed P-Value for Normal Approximation				0.0500

Figure V-36. Mann-Whitney U Test Results for Congruency of Performance Criteria and Depot Objectives by Organizational Levels (Cont'd)

groups. This difference is evident in the chart in Figure V-35.

From the survey and test results reported in Figures V-35 and V-36, one can see that a number of managers above the first-line level perceive an incongruency between their organizations' performance criteria and objectives. This perception probably stems from the fact that the center command section is primarily concerned about the traditional AFLC labor efficiency, OPMD, and manpower indicators. Of course, many of these indicators are too aggregated to really be meaningful, and few of them point out where problems exist or tell management whether the right products were repaired and delivered on time. However, because the center focuses on efficiency, the directorates' management reviews tend to concentrate on this area. The monthly data that the aircraft production division sends to the center is heavily slanted toward labor and material utilization criteria. Fortunately, the LAB chief evaluates his branches on their ability to meet due dates and initiate process improvements. The aircraft directorate does compile various quality indicators each month and has begun looking at FCF rates to pinpoint problems in the repair process.

LI's pneudraulics division examines production, material (supply), and quality performance on a monthly basis. Pie charts and bar graphs, similar to those used in the quality and material portions of the LIH review, would enhance some of the division's production charts. The

production portion, however, also contains information on engineering and training activities, two areas often ignored by AFLC maintenance units and not addressed by any of the aircraft briefings reviewed. As the LIH division is already looking at items like engineering change requests received, it may also wish to begin tracking the number of days required to process these requests.

In addition to not including any information on engineering performance, the F-111 SPM monthly review does not devote much attention to critical items or include any information on the leading F-111 MICAP items. Rather than highlighting SPM engineering support and AFLC material support problems, this review seems more concerned with presenting a detailed compilation of FMC rates and aircraft and engine status at all the F-111 operational units. To present a complete picture of individual weapon system support and status, LA might consider combining the information provided by LAB with that from the SPM reviews (F-111 and A-10 aircraft only). Of course, the SM-ALC commander may prefer to review performance on a functional (directorate) basis instead. To ensure survival in AFLC's new competitive business environment, SM-ALC and the aircraft directorate have established some very logical and detailed goals. A number of these goals even include objectives for developing defect and cycle time measures and customer satisfaction indicators. By encouraging directorates to focus future management reviews on these

type of criteria, rather than on efficiency and utilization indicators, the center should be able to achieve its overall goal of being competitive and providing superior customer support.

System Constraints

The constraints discussed in this case are incorporated in the ECE diagram included at the end of the A-10 case. For F-111 depot maintenance, the undesirable effects resulting from the system constraints revolve around parts availability and physical space limitations in the aircraft service branch's facilities. While some of the parts problems are caused by late deliveries from suppliers, many of the difficulties, especially in LIH, stem from routing delays in the TI backshops. These delays eventually impact LAB and create support problems for a number of SM-ALC's maintenance shops. The routing PAT has already identified the causes of many delays. Hopefully, this team can implement some solutions which will resolve this long-standing SM-ALC problem.

In LAB, the inability to hire entry-level workers will ultimately result in a shortage of fully qualified sheet metal, electrical, hydraulic, and general aircraft mechanics. In the meantime, the hiring and promotions freezes mean that LAB is unable to man its bottleneck facilities 24 hours a day. Consequently, the division is short of space in these areas. The nature of the FY 1992 workload only exacerbates the space shortfalls. Nothing

will aggravate the space problem more than the tripling of the KC-135 workload. These aircraft are four times as large as the fighters for which LA's facilities were built. Accommodating them into the depot maintenance flow will be a real challenge for LAB and LABR.

A-10 Depot Maintenance

AFLC Goals and Depot Objectives

Figure V-37 shows the numerical ratings given by the LA, LI, and TI directorate and division chiefs on the congruency between AFLC goals and depot objectives. The large p-value associated with the Mann-Whitney U test indicates that no significant differences existed between the rankings of the aircraft (LA) and support (LI and TI) directors and division chiefs at the .01 and .05 levels of significance. From the numerical ratings, it is evident that all division chiefs believe that their directorate and depot objectives support the AFLC goals to a significant degree. On the other hand, the three directorate heads believe that these three sets of goals and objectives support each other to a great extent.

In interviewing the LI and TI directors, it was evident that these directorates are concerned about making a profit, satisfying their customers, and providing a positive work environment for their employees. However, because the LI and TI organizations did not make any written goals and objectives available to this researcher, a goal comparison chart was not developed for this case. Some of the

Numerical Ratings		
Unit	Directorate	Division
LA	4	3,3
LI	4	3
TI	4	3
Average	4.00	3

Mann-Whitney U Test				
Function	Rand Sum	Sample Size	U Stat	Average Rank
Aircraft	11.00	3	5.000	3.7
Support	17.00	4	7.000	4.3
Total	28.00	7		
Two-Tailed P-Value for Normal Approximation				0.8597

Figure V-37. Numerical Ratings and Mann-Whitney U Test Results for Congruency of AFLC Goals and Depot Objectives

divisions in TI and LI do have stated goals or objectives. For example, the objectives of TI's NDI division are customer satisfaction, remaining technologically advanced, and supporting marketing efforts. To provide direction and focus for their directorates, TI and LI might consider formulating some goals or objectives and distributing them to their divisions.

Competitive Edges

Directorate, division, and branch chiefs and first-line supervisors were asked to rank the six competitive edges on the basis of unit objectives and of management indicators. Friedman Two-Way Analysis of Variance of Ranks tests showed that, on the basis of both objectives and criteria, significant differences existed between the mean ranks of the competitive edges themselves at the .01 and.05 significance levels. This conclusion was based on the small p-values associated with the competitive edges factor. The test results for each set of rankings are given in Figure V-38. The Bonferroni Pairwise Comparison test results shown in Figure V-39 highlight where the differences exist.

On the basis of unit objectives, A-10 managers regarded quality and cost as the most critical competitive edges and lead time and flexibility as the least important edges. Innovation and delivery appear to be considered neither critical nor unimportant. On the basis of performance criteria, delivery, along with cost and quality, is

Friedman Two-Way Nonparametric Analysis of Ranks		
Competitive Edges	Mean Rank	Sample Size
Cost	2.75	16
Delivery	3.44	16
Flexibility	4.53	16
Innovation	4.13	16
Lead Time	4.47	16
Quality	1.69	16
Friedman Statistic		28.60
P-Value		0.0000
Degrees of Freedom		5

Friedman Two-Way Nonparametric Analysis of Ranks		
Competitive Edges	Mean Rank	Sample Size
Cost	1.75	16
Quality	2.25	16
Lead Time	4.75	16
Delivery	2.94	16
Flexibility	4.63	16
Innovation	4.69	16
Friedman Statistic		41.96
P-Value, Chi-Squared Approximation		0.0000
Degrees of Freedom		5

Figure V-38. Friedman Two-Way Analysis of Variance of Ranks Results: A-10 Depot Maintenance Competitive Edge Rankings by Objectives (top) and by Criteria (bottom)

A-10 Pairwise Comparison of
Competitive Edge Means by Objectives

Quality	Cost	Delivery	Innovation	Lead Time	Flexibility
1.69	2.75	3.44	4.13	4.47	4.53

NOTE: Means which are underlined are not significantly different

A-10 Pairwise Comparison of
Competitive Edge Means by Objectives

Cost	Quality	Delivery	Flexibility	Innovation	Lead Time
1.75	2.25	2.94	4.63	4.69	4.75

NOTE: Means which are underlined are not significantly different

Figure V-39. Bonferroni Pairwise Comparison Results

classified as a critical competitive edge. Flexibility, innovation, and lead time are clearly considered to be less important than cost, quality, and delivery. The ranking of cost as the most important competitive edge is certainly consistent with the emphasis that the directorates, particularly LI, place on this element in their management reviews.

Using the median test, the survey results were analyzed to determine whether differences existed between higher-level (directorate and division chiefs) and lower-level (branch chiefs and first-line supervisors) LA, LI, and TI managers on the rankings of individual competitive edges. On the basis of these two organizational levels, no significant differences existed between the ranks of the competitive edges at the .01 and .05 significance levels. Median tests were also used to ascertain whether differences existed between all levels of aircraft (LA) managers and of managers from the supporting directorates (LI and TI) on individual competitive edge rankings. On the basis of performance criteria, there were no significant differences at either the .01 or .05 levels of significance. On the basis of unit objectives, though, differences did exist at the .05 level of significance. This conclusion was based on the large chi square and small p-values associated with the two median tests shown in Figure V-40. Aircraft managers did not consider delivery to be as important as did support managers. While most aircraft managers ranked delivery as

Median Test for Delivery = Function

	Function: Aircraft	Function: Support	Total
Above Median	5	2	7
Below Median	1	5	6
Total	6	7	13
Ties w/Median	2	1	3
Median Value			3.000
Chi-Square			3.900
P-Value			0.0483
Degrees of Freedom			1

Median Test for Innovation = Function

	Function: Aircraft	Function: Support	Total
Above Median	1	6	7
Below Median	5	2	7
Total	6	8	14
Ties w/Median	2	0	2
Median Value			4.000
Chi-Square			4.670
P-Value			0.0308
Degrees of Freedom			1

Figure V-40. Median Test Results for A-10 Depot Maintenance Competitive Edge Rankings by Objectives and by Function

the second or third most critical edge on the basis of criteria, by objectives they tended to rank other elements, such as lead time and innovation, ahead of delivery. They believed that these other elements were essential for achieving timely due date performance. In addition, aircraft managers regarded innovation as being a much more critical objective/competitive edge than did support managers. Similar differences concerning the importance of innovation were seen in the F-111 case. Interestingly, the innovation rankings of LI's multi-avionics support branch and TI's advanced structures branch were much higher than those of the LI and TI directors.

Performance Criteria

Managers at directorate, division, branch, and first-line levels were asked to rate the extent to which they believed their organizations' management indicators supported their depot and directorate objectives and command goals. Figure V-41 shows the actual ratings of LI and TI managers and the LA director and the average ratings of LA division, branch, and first-line supervisors. Most managers rated the congruency between performance criteria and depot objectives as significant. However, the TI director, TIMC's production chief, and LI's avionics chief recognized a disconnect between their organizations' performance criteria and objectives. Mann-Whitney U tests were conducted on the survey results to determine whether significant differences

Congruency of Performance Criteria and Depot Objectives				
Level/Org	Directorate	Division	Unit	Subunit
LA	3	3	3	4
LI	3	2	4	3
TI	2	3	3	2

Figure V-41. A-10 Depot Maintenance Ratings for the Congruency of Performance Criteria and Depot Objectives by Organizational Levels

existed between the mean rankings of the managers at the four different levels. The results of these tests, provided in Figure V-42, indicate that, at the .01 and .05 significance levels, no significant differences existed between the mean rankings of each of the four groups of managers. This conclusion was based on the large p-values associated with each test. On the basis of p-values, the agreement of the directorate versus division and branch versus first-line supervisor rankings is particularly high.

Considering the extent to which SM-ALC and the TI and LI directorates emphasize efficiency criteria, it is gratifying to observe that at least three managers from these organizations realize that these type of indicators are counterproductive to depot goals and objectives. Though TI has no formal management review, the directorate indicated in its pre-visit survey that direct labor effectiveness and sick leave are the primary indicators it uses to evaluate performance. Likewise, LI's avionics division sees labor effectiveness as a key criterion for evaluating its own performance and that of its branches. Indeed, two-thirds of the slides in LI's monthly management review are concerned with efficiency-related indicators. Though this review tends to focus on one area, the manner in which the information is presented (bar graphs by division) makes it easy to comprehend and compare LI division performance. While quality performance is probably reviewed in a separate forum, it is surprising that this management review does not

Directorate -vs- Division Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Directorate	11.50	3	5.500	3.8
Division	16.50	4	6.500	4.1
Total	28.00	7		
Two-Tailed P-Value for Normal Approximation				1.0000

Directorate -vs- Branch Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Directorate	10.50	3	4.500	3.5
Branch	25.50	5	10.500	5.1
Total	36.00	8		
Two-Tailed P-Value for Normal Approximation				0.4561

Directorate -vs- First-Line Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Directorate	9.50	3	3.500	3.2
First-Line	18.50	4	8.500	4.6
Total	28.00	7		
Two-Tailed P-Value for Normal Approximation				0.4795

Figure V-42. Mann-Whitney U Test Results for Congruency of Performance Criteria and Depot Objectives by Organizational Levels

Division -vs- Branch Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Division	16.50	4	6.50	4.1
Branch	28.50	5	13.50	5.7
Total	45.00	9		
Two-Tailed P-Value for Normal Approximation				0.4624

Division -vs- First-Line Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Division	15.00	4	5.000	3.8
First-Line	21.00	4	11.000	5.3
Total	36.00	8		
Two-Tailed P-Value for Normal Approximation				0.4705

Branch -vs- First-Line Mann-Whitney U Test				
Level of Organization	Rank Sum	Sample Size	U Stat	Average Rank
Branch	24.50	5	9.500	4.9
First-Line	20.50	4	10.500	5.1
Total	45.00	9		
Two-Tailed P-Value for Normal Approximation				1.0000

Figure V-42. Mann-Whitney U Test Results for Congruency of Performance Criteria and Depot Objectives by Organizational Levels (Cont'd)

examine directorate performance in such areas as quality, training, and engineering.

Although LI and TI indicators tend to focus on efficiency, the division-level and branch-level management reviews generally look at a broader spectrum of performance. The LIA and TIMC review devote a considerable amount of attention to MISTR production and QDR statistics. The TIMC briefing also examines performance in the areas of safety, training, engineering, and waste management. Of course, hazardous waste management is a prime concern of the TI director. What is especially noteworthy, however, is the branch's examination of engineering performance. Typically, performance in this area is only formally reviewed by directorates and divisions.

System Constraints

The ECE diagram in Figure V-43 shows the impact of various constraints on F-111 and A-10 depot maintenance performance. The numbers in parentheses in this section refer to the numbered blocks in Figure V-43. Throughput (T), inventory (I), and operating expense (OE) are the three criteria used to measure F-111 and A-10 depot maintenance performance. Reductions in T and increases in I and OE can be traced to the following core constraints: an emphasis on efficiency-based performance criteria (1), routing procedures in the TI backshops (20), restrictive personnel policies (25), the AFLC hiring and promotion freezes (36), the AFLC's assignment of depot workloads (39), and

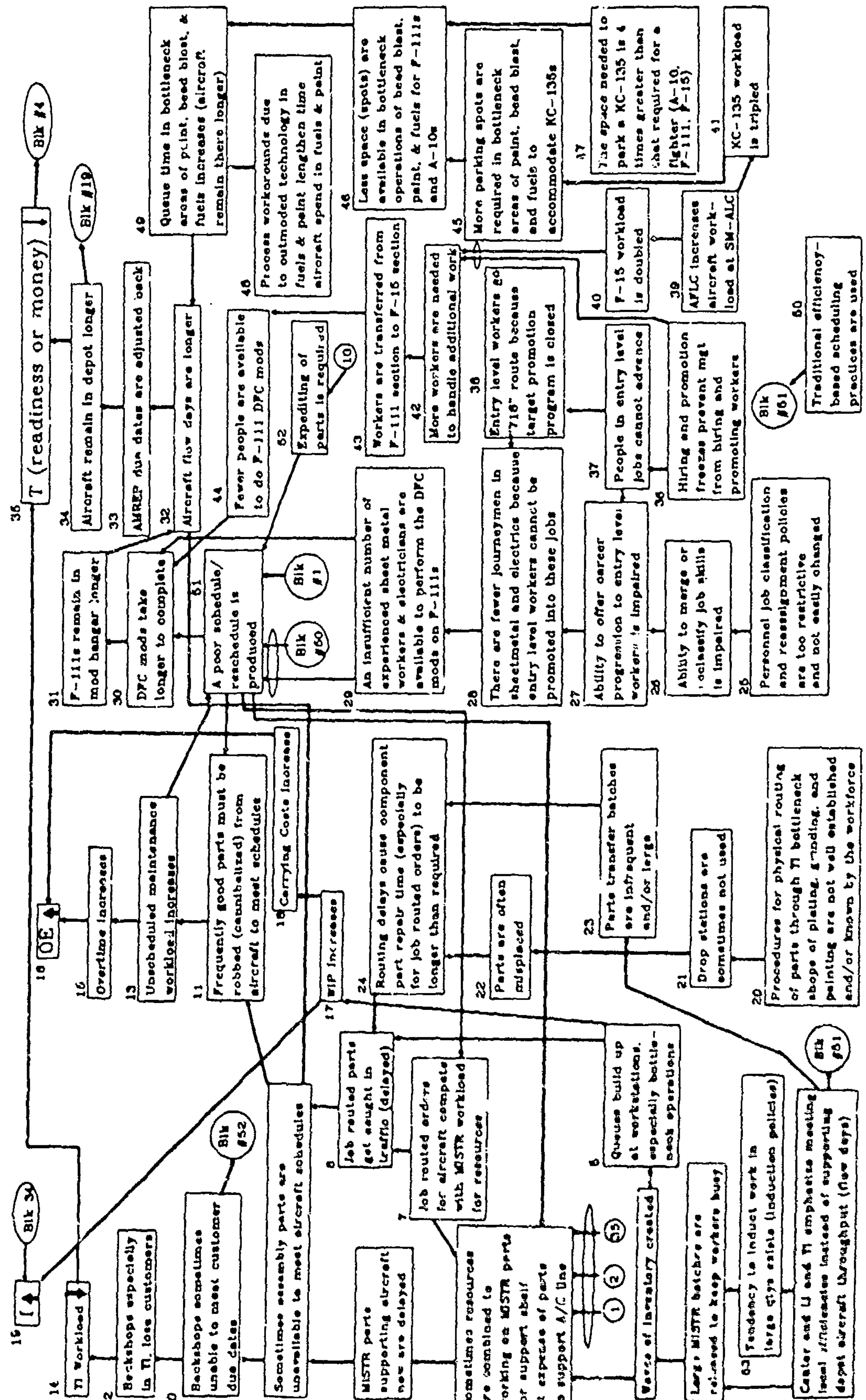


Figure V-43. ECE Diagram for F-111 and A-10 Depot Maintenance

traditional efficiency-based scheduling practices (50). Because the effects of efficiency-based scheduling practices and poor schedules have been examined in detail in the C-141 and F-16 cases, the scheduling discussion for this ECE diagram simply lists these effects. Also, while the diagram does not contain a block for workforce mindset, the reluctance of many workers to accept the TQM philosophy certainly impacts all areas of performance.

By now the effects of the first core problem, the emphasis on efficiency-based performance criteria (1), are familiar to the reader. Due to this emphasis (1), the LI and TI backshops tend to induct work in large quantities (53), particularly at the beginning of a month or a quarter. Induction policies (53) cause large MISTR batches to be released to the shop floor (2), which creates waves of inventory (3), causing queues to build at workstations (5). Lengthy queues (5) result in job routed parts being delayed (8), causing assembly parts to be unavailable to meet aircraft schedules (9). Consequently, often good parts must be robbed from aircraft (11), causing unscheduled maintenance to increase (13). More unscheduled maintenance (13) leads to more overtime (15), which increases overall operating expenses (16). Unavailability of assembly parts also causes aircraft flow days to be longer than anticipated (32). Furthermore, the lengthy queues (5) also cause WIP to increase (17), resulting in higher carrying costs (18) and higher operating expenses (16). Of course, increases in WIP

(17) lead to higher overall inventory (19).

The fact that job routed orders for aircraft compete with MISTR workload for resources (7) also delays job routed parts (8), causing assembly parts not to be available to support aircraft schedules (9). This fact (7) and the waves of inventory (3) sometimes cause resources to be committed to working on MISTR parts for supply at the expense of parts for aircraft (4). Thus, MISTR parts are delayed (6), and assembly parts are unavailable to meet aircraft schedules (9). As a result, backshops are sometimes unable to meet customer due dates (10), which causes them to lose customers (12). Lost customers (12) lead to a decrease in workload, especially for TI (14), which results in a decline for system throughput (35). The inability of backshops to meet customer due dates also causes parts expediting (52), which sometimes makes rescheduling necessary (51). Finally, the emphasis on meeting local efficiencies (1), coupled with the release of large MISTR batches to the shop floor (2) and reductions in depot throughput (35), sometimes causes resources to be committed to working on MISTR parts for supply at the expense of parts for aircraft (4). Consequently, MISTR parts for aircraft are delayed (6), and assembly parts are not available when needed (9).

Traditional efficiency-based scheduling practices (50) represent the second core problem. This problem (50), combined with an insufficient number of electricians and sheet metal workers (29), causes poor schedules and

rescheduling (51). Poor schedules (51) are also the result of efficiency-based performance criteria (1) and unscheduled maintenance (13). Due to poor schedules and rescheduling (51), sometimes resources are committed to working on MISTR resources for supply at the expense of those for aircraft (4), job routed orders receive inadequate attention (7), parts cannibalization is necessary (11), and digital flight control (DFC) modifications take longer to complete (30). Because DFC modifications take longer to complete (30), F-111s remain in the mod hangar longer (31), causing aircraft flow days to be longer than expected (32). Longer aircraft flow days (32) cause AMREP due dates to be adjusted back (33). Consequently, more aircraft remain in the depot longer (34), resulting in an increase in aircraft depot inventory (19) and a decline in depot throughput (35).

Reductions in T may also be traced to the third core constraint, the poor procedures for the physical routing of parts through the TI bottleneck shops (20). Due to this core problem (20), drop stations are sometimes not used (21), causing parts to be misplaced (22) and routing delays to occur (24). In addition, the emphasis on efficiency indicators (1) causes parts transfer batches to be large and/or made infrequently (23), resulting in routing delays that cause component repair times to be longer than required (24). As a result, job routed items get delayed (8).

The fourth core constraint, restrictive personnel job classification and reassignment policies (25), impairs the

ability of depot managers to merge or reclassify job skills (26), which in turn impairs the ability of these managers to offer career progression to entry level workers (27). As a result, there are fewer journeymen in the electrics and sheet metal job skills (28), causing an insufficient number of workers in these skills to be available to perform DFC modifications (29). Thus, the DFC modifications take longer to complete (30). Career progression (27) is also hampered by the fact that people in entry level jobs cannot advance (37), due to the promotion freeze (36) (the fifth core problem). Furthermore, because entry-level personnel cannot advance (37), they seek alternative routes out of these jobs (38), which results in fewer electrics and sheet metal journeymen (28).

The sixth core constraint concerns the increase in SM-ALC's FY92 aircraft workload (39). Due to this increase (39), the F-15 workload has doubled (40) and the KC-135 workload has tripled (41). The doubling of the F-15 workload (40), along with the hiring and promotion freezes (36), means that more workers are needed to handle the additional work (42), causing some workers to be transferred from the F-111 section to the F-15 section (43). Transfer of workers (43) causes fewer workers to be available to perform DFC modifications (44), which in turn lengthens the time required to complete DFC modifications (30). Tripling of the KC-135 workload (41) means that more parking spaces will be required in LA's bottleneck areas. The need for

more parking spaces (45), plus the fact that a KC-135 requires four times more parking space than a fighter aircraft (47), causes less space to be available in the bottleneck facilities (46). Consequently, aircraft remain in these facilities longer (49), which increases aircraft flow days (32) and ultimately decreases depot throughput (35). Bottleneck queue time (49) is also longer because of the process workarounds necessary in fuels and paint (48).

In summary, two of SM-ALC's core constraints (1 and 50) can be traced to traditional cost accounting philosophy, while two others (25 and 36) are the result of DOD and AFLC personnel policies. The remaining two constraints (20 and 39) will likely be alleviated in the short term. However, the other four constraints will probably only be eliminated in the long term. Even though depot managers can deemphasize the use of efficiency-based performance criteria and scheduling practices, there is little they can do to change AFLC and DOD personnel policies. Due to the impact of the hiring and promotion freezes and the AFLC workload increase on SM-ALC depot maintenance, this ECE is the best illustration in this dissertation of the negative effects of policy and of the fact that the ALCs operate as part of the AFLC depot maintenance system, rather than in isolation.

Cross-Case Analysis

AFLC Goals and Depot Objectives

For the first research question, tables comparing the average numerical ratings on the congruency between AFLC

goals and depot objectives, the Mann-Whitney U test p-values for congruency of AFLC goals and depot objectives, and the goals and objectives of AFLC, WR-ALC, OO-ALC, and SM-ALC were developed. Table V-1 shows the average numerical ratings on the congruency between AFLC goals and depot objectives that were given by the 24 aircraft and support directorate and division chiefs surveyed in this study. Overall, all directors and all support managers rated the congruency higher than did all division chiefs and all aircraft managers. As a whole, directors probably have a clearer understanding of AFLC goals and depot objectives than division chiefs. Consequently, they may have tended to give higher ratings for the congruency between these goals and objectives. Also, as a rule, aircraft managers tend to be more concerned with meeting AMREP due dates and producing quality aircraft than with such AFLC goals as the quality of life and requirements forecasting. Hence, they may be less likely than support managers to view the congruency between AFLC goals and depot objectives as great (a rating of 4).

Of the four particular groups of managers, the aircraft directors' congruency ratings were the highest and those of the aircraft division chiefs were definitely the lowest. While the congruency ratings for support directors and division chiefs were very close, those for the two groups of aircraft managers differed by 0.58, on a scale of 1 to 4.

Table V-1

Numerical Ratings and Mann-Whitney P-Values for Congruency of AFLC Goals and Depot Objectives for all Research Participants at WR-ALC, OO-ALC, and SM-ALC

Numerical Rating Averages			
	Organizational Level		
Function	Directorate	Division	Overall Average
Aircraft	3.75 (n=4)	3.17 (n=6)	3.4 (n=10)
Support	3.60 (n=5)	3.56 (n=9)	3.57 (n=14)
Overall Average	3.67 (n=9)	3.40 (n=15)	

Comparison of Mann-Whitney U Test P-Values	
Organizations/Case	P-Value
C-130	0.7728
C-141	0.8170
F-4	1.0000
F-16	1.0000
F-111	0.4795
A-10	0.8597

There are two possible explanations for this rating discrepancy. First, aircraft division chiefs may not be as aware of depot objectives as support division chiefs and thus may be less likely to believe that these objectives support the AFLC goals to a great extent. Second, aircraft division chiefs tend to see timely aircraft delivery as a prime depot objective. Because the AFLC goals are oriented toward people and quality and do not directly address on-time delivery, these managers may be less inclined to believe that depot objectives support AFLC goals to a great extent.

Table V-1 also provides Mann-Whitney U test p-values for how aircraft and support managers at the six depot maintenance organizations rated the congruency of AFLC goals and depot objectives. Though the ratings of F-111 aircraft and support managers only showed modest agreement, the ratings of these two groups of managers at the other five depot maintenance organizations exhibited a high degree of similarity. The agreement between aircraft and support managers in the F-4 and F-16 organizations at OO-ALC was particularly strong. As a rule, division chiefs tended to give a rating of 3 and directors a rating of 4 for the congruency of AFLC goals and depot objectives, which led to a fairly equal mix of 3s and 4s for the aircraft and support sets of ratings as a whole. However, in the F-111 case, one of the support division chiefs rated this congruency as great (a rating of 4) rather than significant (a rating of

3), which resulted in a majority of 4s for the support rankings.

Even though many of the directors interviewed believed that their depot objectives supported the AFLC goals to a great extent, a number of them pointed out that the command goals failed to address business issues and provided little guidance for depot maintenance. A member of the AFLC headquarters performance measurement development team commented that the goals were not based in reality. Table V-2 compares the topics covered by the AFLC goals and those at the Warner Robins, Ogden, and Sacramento ALCs. While the AFLC goals are too broad to be useful, the center goals are less general and range from WR-ALC's concise mission statement to OO-ALC's four areas of focus to the detailed objectives and subobjectives published by SM-ALC. The WR-ALC goal is concerned with the timely delivery of quality products at the least cost. The OO-ALC areas of focus expand on AFLC's continuous improvement and customer satisfaction goals and address a fourth area, competition, that is totally ignored by the AFLC goals. Of the goals for the three ALCs in this study, those for SM-ALC were the most detailed, the most oriented toward a true business environment, and the only ones to include offices of primary responsibility (OPRs) and milestone dates for achievement.

Likewise, the goals and objectives of SM-ALC's aircraft directorate included OPRs and target dates and were the most detailed of any of the directorates examined in this study.

Table V-2

Comparison of AFLC, WR-ALC, OO-ALC, and SM-ALC Goals and Objectives

Comparison of Goals Across Organizations				
Goal/Objective	AFLC	WR-ALC	OO-ALC	SM-ALC
Personal Accountability	X			LA only
Competitive/ Supplier of Choice			X	X
Continuous/Process Improvement	X	C-130 & C-141 only	OO-ALC & LI only	X
Customer Satisfaction	X	X	X	X
People	X		X	LA only
Cost Reduction to Improve Profitability		X		
Quality/TQM	X	X	LA only	
Teamwork			X	SM-ALC only
Timeliness (Delivery)		X		
Viable Performance Indicators			LA only	X
Directorates Included		C-130 C-141 LY, LI	LA & LI	LA only

X = The center (ALC) and each directorate studied at that ALC have established a goal/objective pertaining to the goal/objective in the left-hand column

In general, the aircraft directorates in this study (i.e., the C-130 and C-141 directorates at WR-ALC and the LA directorates at OO-ALC and SM-ALC) had developed much more specific objectives than the support organizations at these centers. SM-ALC's TI and LI directorates did not appear to have any published objectives. WR-ALC's avionics directorate and OO-ALC's LI directorate established goals which closely paralleled the mission statement and areas of focus for their centers. The goals of WR-ALC's TI directorate were the most specific of all the support directorates visited. Like the WR-ALC TI director, the C-130 and C-141 directors had developed several goals and objectives with specific targets, such as 30 annual PDMs and 130 flow days. Although the OO-ALC LA goals did not include specific targets, the goals for its aircraft operations and technical repair divisions were the most detailed division goals examined in this study.

This researcher believes that the center and directorate objectives at WR-ALC, OO-ALC, and SM-ALC support the command goals to a significant degree. Unfortunately, rather than addressing problems, the AFLC goals tend to summarize what the command should be doing on a routine basis to accomplish its mission. Instead, these goals should be more concrete and should be revised to reflect the realities of competition and the deficiencies that exist with logistics support. A worthy command goal that needs to be addressed in greater detail is the personal

accountability goal. This goal deals with a topic which concerns workers and managers alike and requires major changes if AFLC is to effectively compete. However, accountability is a sensitive issue and was specified as a unit objective only by SM-ALC's aircraft directorate. SM-ALC and the LA directorates at SM-ALC and OO-ALC were also the only organizations that had objectives related to management indicators (i.e., performance criteria). Of course, the development of viable indicators is a difficult task for which the payoffs are great in the long term but are only minimal in the short term.

Competitive Edges

As a part of the second research question, managers at four levels in six depot maintenance organizations were asked to evaluate, on the basis of unit objectives and of performance criteria, the importance of six competitive edges for accomplishing their organizational mission. The rank order results obtained from Friedman Two-Way Analysis of Variance of Ranks tests conducted for each category and each maintenance organization (case) are provided in Table V-3. On the basis of both unit objectives and management indicators, all organizations ranked quality, cost, and delivery among the three most critical competitive edges and lead time, flexibility, and innovation among the least important edges. In both the objectives and criteria categories, except for the A-10 rankings by criteria, quality was consistently ranked as the most critical

Table V-3

Cross-Case Comparison of Competitive Edge Rank Order by Objectives and by Criteria

Rank Order	C-130	C-141	F-4	F-16	F-111	A-10
Rank Order of Competitive Edges by Objectives						
1	Quality	Quality	Quality	Quality	Quality	Quality
2	Delivery	Delivery	Delivery	Delivery	Cost	Cost
3	Cost	Cost	Cost	Cost	Delivery	Delivery
4	Lead Time	Lead Time	Flexibility	Lead Time	Lead Time	Innovation
5	Flexibility	Innovation	Lead Time	Innovation	Flexibility	Lead Time
6	Innovation	Flexibility	Innovation	Flexibility	Innovation	Flexibility
Rank Order of Competitive Edges by Criteria						
1	Quality	Quality	Quality	Quality	Quality	Cost
2	Delivery	Cost	Cost	Cost	Cost	Quality
3	Cost	Delivery	Delivery	Delivery	Delivery	Delivery
4	Lead Time	Lead Time	Lead Time	Lead Time	Lead Time	Flexibility
5	Flexibility	Innovation	Innovation	Flexibility	Innovation	Innovation
[illegible]	Innovation	Flexibility	Flexibility	Innovation	Flexibility	Lead Time

competitive edge. By objectives, quality, delivery, and cost, in that order, were ranked as the most important edges by the C-130, C-141, F-4, and F-16 depot maintenance organizations. By criteria, cost, rather than delivery, was the second most important competitive edge for the C-141, F-4, F-16, and F-111 organizations. In this category, the A-10 managers ranked cost as the most important edge. By objectives, cost was also ranked as the second most critical edge by the two SM-ALC depot maintenance organizations.

In the objectives category, managers from all organizations ranked quality as the most important edge. Four of the organizations considered lead time to be the fourth most critical edge. The F-4 and A-10 organizations, however, ranked flexibility and innovation in the number four position, respectively. Because the F-4 depot maintenance workload is rapidly declining, F-4 managers probably believe that they will need to become more flexible in order to accommodate shifts in workload and personnel. The higher ranking of innovation by A-10 managers might be a consequence of the LASTE program. This modification employs state-of-the-art software and is the most significant one ever installed on the A-10 aircraft. As a rule, managers at higher organizational levels tended to regard flexibility and innovation as being more important, in terms of objectives, than did supervisors at branch and first-line levels. Directors and division chiefs considered flexibility and innovation to be objectives that were

essential for their organizations to meet quality, cost, and delivery standards.

Even though the actual elements included in the top and bottom halves of the rankings were the same in both categories for all cases, in the criteria category the differences between the upper and lower rankings were more distinct. The C-130, F-4, and A-10 organizations clearly regarded quality, cost, and delivery as being more critical than the remaining three elements. Though the C-141, F-16, and F-111 managers ranked these same three elements as being the most critical, their composite rankings for delivery were not significantly higher than those for lead time. Thus, for these three organizations, delivery and lead time were ranked as neither especially critical nor particularly unimportant. This researcher believes that the criteria category more accurately reflects how depot managers at various levels perceive that their organizations compete. Hence, based on the results in Table V-3, the AFLC depot maintenance organizations examined in this study tend to compete on the basis of quality, cost, and delivery, in that order.

While the statistical test results indicate that significant differences existed between the rankings of the competitive edges themselves, no significant differences were found on how managers at the four organizational levels ranked these edges. On the basis of organizational function (aircraft versus support), though, out of a total of 72

comparisons, seven instances of significant differences were obtained. Five of these instances were on the basis of objectives and the remaining two were in the criteria category. On the basis of performance criteria, C-141 support managers considered flexibility to be more important than did C-141 aircraft managers. In this category, F-111 support managers deemed lead time to be more critical than did F-111 aircraft supervisors. On the basis of unit objectives, significant differences were found in the rankings of flexibility, delivery, and innovation. C-141 support managers also regarded flexibility to be a more important objective than did C-141 aircraft supervisors. Surprisingly, F-4 and A-10 support supervisors viewed delivery to be a more important objective than did the aircraft managers for these organizations. Finally, SM-ALC's A-10 and F-111 aircraft managers ranked innovation much higher than their support counterparts ranked it. On the basis of function, no significant differences existed in the C-130 and F-16 depot maintenance organizations, and no differences were found in any organization on the rankings of quality and cost.

Performance Criteria

Introduction

The third research question involves assessing the congruency of AFLC performance criteria and depot objectives, examining current AFLC performance criteria, and proposing new performance criteria. The criteria proposed

by this researcher are outlined in Figure VI-4. The first portion of this section discusses the similarities and differences across the six depot maintenance organizations on the ratings for congruency of performance criteria and depot objectives. Two tables comparing the average numerical ratings and the Mann-Whitney U test p-values for congruency of performance criteria and depot objectives are provided. The second part of this section compares the monthly performance reviews conducted at the three ALCs in this study as well as the primary performance criteria employed by the directorates examined at these depots. This section concludes with a comparison table listing nine of the AFLC's more credible management indicators and the directorates at WR-ALC, OO-ALC, and SM-ALC in which they are used.

Ratings for Congruency of Performance Criteria and Depot Objectives

Managers at the directorate, division, branch, and first-line levels were asked to rate the extent to which they believed their organizations' management indicators supported their depot and directorate objectives and command goals. The numerical ratings from each level of each directorate in this study were averaged and appear in Table V-4. Overall averages for each organizational level were also computed. Across the four levels, the directorate-level average was the lowest, and the overall average for first-line supervisors was the highest. The division and

Table V-4

AFLC Depot Maintenance Ratings for Congruency of Performance Criteria and Depot Objectives by Organizational Levels

Numerical Rating Averages					
ALC	Organization	Directorate	Division	Branch	First-Line
WR	C-130	3	3	3.00 (n=3)	2.67 (n=3)
	C-141	3	3	3.00 (n=6)	3.83 (n=6)
	LY	3	4	3.25 (n=4)	3.00 (n=4)
	TI	2	4 (n=2)	3.4 (n=5)	3.40 (n=5)
OO	LA	4	3.50 (n=2)	3.50 (n=6)	3.14 (n=7)
	LI	4	3.00 (n=2)	3.00 (n=2)	3.43 (n=7)
SM	LA	3	3.00 (n=2)	2.80 (n=5)	3.75 (n=4)
	LI	3	2.50 (n=2)	3.50 (n=2)	3.50 (n=2)
	TI	2	2.50 (n=2)	2.50 (n=2)	3.00 (n=2)
Overall Average		3.00 (n=9)	3.13 (n=15)	3.14 (n=35)	3.35 (n=40)

branch averages were nearly identical and were about halfway between those of the other two levels. These results were the ones expected and are consistent with the data obtained in interviews. In general, the managers at higher organizational levels were more cognizant of problems with AFLC management indicators than were those at the lower levels. In fact, both TI directors in the study rated the congruency of performance criteria and depot objectives as being only slight. On the other hand, the average ratings for the C-141 first-line supervisors and the SM-ALC aircraft directorate's first-line managers averaged nearly 4 and were among the highest of any of the groups in this study. Of course, exceptions to this trend did exist. For example, both the LA and LI directors at OO-ALC rated the congruency between performance criteria and depot objectives as great. Based on the management indicators used by LA, the aircraft directorate rating is not illogical. However, taking into account the inputs that LI submitted for the DDPMS criteria, the LI rating is questionable. By contrast, the average rating of 2.67 that was given by C-130 first-line supervisors was lower than the overall directorate average and particularly low for this organizational level. Because only three individuals were surveyed, no generalizations about how C-130 first-line supervisors rate the congruency of performance criteria and depot objectives can be made. The rating does indicate, though, that at least a few AFLC

first-line supervisors recognize the disconnect between efficiency criteria and their organizations' objectives.

Mann-Whitney U tests were also conducted on the survey results for each case to determine whether significant differences existed between the mean rankings of the managers at the four levels. The p-values from these tests are summarized in Table V-5. While no significant differences were found, the p-value of 0.0500 for the F-111 branch chiefs versus first-line supervisor ratings does indicate that there were substantial differences in how these two groups rated the congruency of performance criteria and depot objectives. The p-values for the F-111 directorate versus first-line and the F-111 division versus first-line sets of rankings are also much lower than those of any other group (other than the F-111 branch versus first-line). Therefore, it appears that the F-111 first-line supervisors' ratings were considerably, though not significantly, different from those of F-111 managers at the three higher levels of that organization. On the other hand, there was very strong agreement between the ratings of the F-111 directorate and division levels and directorate and branch levels. The A-10 directorate versus division ratings also displayed high agreement. Likewise, the branch versus first-line p-values were extremely high for all organizations except F-111 and C-141 depot maintenance.

Within levels, the C-130 directorate versus division ratings displayed the least agreement of all ratings in this

Table V-5

Comparison of Mann-Whitney U Test P-Values for Congruency of Performance Criteria and Depot Objectives by Organizational Levels for all Research Participants

Comparison of Mann-Whitney U Test P-Values						
Case	Directorate vs Division	Directorate vs Branch	Directorate vs First-Line	Division vs Branch	Division vs First-Line	Branch vs First-Line
C-130	0.2482	0.3173	0.4047	0.3017	0.4386	1.0000
C-141	0.2752	0.7182	0.3123	0.2790	0.6650	0.3556
F-4	0.3865	0.4875	0.3055	0.5959	0.5688	0.9247
F-16	0.7728	0.2472	0.1877	0.4795	0.4250	1.0000
F-111	1.0000	1.0000	0.1116	0.8065	0.0833	0.0500
A-10	1.0000	0.4561	0.4795	0.4624	0.4705	1.0000

category. In the directorate versus branch category, the ratings of F-16 managers were the least similar and those of F-111 managers were the most similar. Not surprisingly, no great similarity was exhibited by any of the directorate versus first-line rankings. At the division versus branch level, the congruency ratings were found to be in the highest agreement for F-111 depot maintenance and in the lowest agreement for the C-141 organization. Conversely, for the division versus first-line level, the C-141 ratings exhibited the highest degree of similarity. At this level, the F-111 managers' ratings were the least similar. Overall, as indicated by p-values, the branch versus first-line p-values exhibited the highest agreement, while those for directorate versus first-line supervisors showed the least similarity. These results are consistent with the survey data obtained at all levels.

ALC and Directorate Performance Criteria

Although all ALCs must submit similar inputs to AFLC headquarters for the DDPMS criteria, the criteria employed by directorates varies, depending on the emphasis of ALC commanders. Of the three depots in this study, performance reviews at center level are the most detailed and formal at WR-ALC. One reason for this detail might be related to the WR-ALC center commander's greater span of control, relative to the other two depots examined in this study. WR-ALC has six product directorates, while OO-ALC and SM-ALC each have four. The WR-ALC commander receives comprehensive monthly

management reviews from each of his six product directorates and a consolidated monthly management review for the center. This consolidated review depicts financial performance for the ALC as a whole, as well as center trends for such areas as sick leave, direct labor effectiveness, and WIP. The management indicators presented in the product directorate reviews are grouped by the categories of throughput, inventory, and operating expense. The C-130 and C-141 reviews cover all facets of logistics management from contracting and item management to depot maintenance. Each of these reviews, as well as the TI monthly review, includes several criteria for engineering performance. Though the avionics directorate's management briefing does not include any engineering indicators, its review of contracting performance is the most thorough of any of the directorate management reviews examined in this study.

The OO-ALC center-level performance reviews are the least structured. The OO-ALC commander holds a monthly progress meeting with his product directors, but, unlike at WR-ALC and SM-ALC, there is no formal slide presentation of various management indicators. As the LI director follows suit, the indicators used by the LI divisions provide the best picture of LI directorate criteria. The LI division indicators are principally concerned with production and material supportability. None of the LI or LA management reviews look at contracting and engineering performance. While performance in these two areas may be covered by the

F-4 and F-16 SPM reviews, the SPM reviews were not examined. OO-ALC's aircraft directorate compiles a monthly maintenance summary which uses the same eight indicators to highlight depot maintenance performance for the F-4, F-16, and C-130 aircraft. This summary contains a balanced mix of information on cost, quality, training, and delivery performance. The LA division management reviews emphasize training to an extent that was not seen in any of the other directorates examined in this study.

Rather than summarizing a directorate's performance, the formal management reviews given to the SM-ALC commander present information on various topics, such as aircraft maintenance, SPM support, and DMIF financial status. Compared to WR-ALC and OO-ALC, SM-ALC places a greater emphasis on efficiency and effectiveness indicators related to direct labor and material utilization. Consequently, the LA, LI, and TI directorates give more weight to these types of indicators, too. By contrast, the OO-ALC LA directorate review, as well as those of the C-141 and avionics directorates at WR-ALC, is virtually devoid of criteria like direct labor effectiveness and OPMD. Unfortunately, the SM-ALC management reviews also devote little attention to assessing contracting and engineering performance. Neither of these areas is addressed by the A-10 and F-111 SPM reviews nor by the LI monthly management review. However, the LI pneudraulics division's production review does present information on engineering change requests,

technical order change requests, and work control documents. This review, along with that of the TI manufacturing division's advanced structures branch, also briefly looks at training. Finally, the aircraft directorate has begun tracking FCF rates to learn where to concentrate process improvement efforts. FCF rates, as well as flight test defects, are also examined by OO-ALC's LA directorate.

Of the three competitive edges identified by this study as being the most critical for AFLC depot maintenance, quality is the one which is the most difficult to measure and the one for which good indicators are most needed. The customer reported defects criterion was employed by every directorate in this study and, for all practical purposes, is the only quality indicator used by AFLC to assess the repair of aircraft and exchangeables. Though this criterion only includes major and critical defects, it would still be useful, provided the QDR reporting system was not so badly abused. Fortunately, by analyzing customer comment cards, organizations like OO-ALC's aircraft directorate and the LI pneudraulics division at SM-ALC are beginning to track the minor quality defects noted by their internal and external customers. FCF rates are another indicator of quality deficiencies and can be particularly useful if the reasons for repeat FCFs are ascribed to the proper aircraft systems and a complete follow-up through all phases of the depot maintenance cycle is undertaken.

In regard to delivery, the productivity measurement matrix indicators of initial AMREP schedule and flow days were probably some of the more valid indicators in that matrix. Over the years the usefulness of the AMREP schedule criterion has been degraded because supervisors typically manipulate the indicator so that late aircraft deliveries are rarely charged to their depot. Flow days is a useful criterion if the days are tracked by aircraft MDS and tail number. The C-130, C-141, and OO-ALC LA directorates use flow days to measure timeliness or delivery. Instead of flow days, the LA directorate at SM-ALC employs the new DDPMS criterion of schedule conformance. The OO-ALC LA delivery indicators are the most detailed of any aircraft directorate in this study. For each of the three types of aircraft it repairs, LA tracks negotiated flow versus actual flow by tail number and the number of days delivered early or late. This directorate, as well as the other three aircraft directorates in this study, also reports scheduled versus actual aircraft production on a monthly basis.

Scheduled versus actual production is the criterion typically used by the support directorates to measure both the production and delivery of exchangeable items. Because nearly all of the items repaired by these organizations are MISTR inputs with 90-day due dates, AFLC traditionally has not been very concerned about timely delivery of exchangeables. With the advent of competition and programs like DRIVE, this attitude is rapidly changing. At WR-ALC,

TI has been monitoring F-15 wing flow days and tracking on-time and late deliveries for job routed items. LY has begun tracking shop flow day reduction and is proposing the implementation of a biweekly MISTR program similar to the biweekly DRIVE program already used by LAR's avionics branch at OO-ALC. Using a two-week, rather than a three-month, window for exchangeable repair would provide better customer support and force support directorates to pay more attention to delivery.

As a result of DOD budget reductions, all directorates in this study now monitor cost and profit/loss status much more closely than in the recent past. Because such a multitude of profit and expense indicators are used by the depot maintenance organizations in this study, no attempt will be made to review all of them. These indicators generally examine various categories of operating expenses and the execution of different types of funds. At directorate level, overtime is one of the expenses often monitored. All organizations in this study, except LI at OO-ALC, formally review overtime usage on a regular basis. At SM-ALC, DMIF profit/loss status and production/delivery performance are reviewed in separate meetings. Although the OO-ALC directorates also have separate meetings for reviewing profit/loss status, cost indicators pertaining to overtime and JON analysis are included in the aircraft production briefings. At WR-ALC, information on operating expenses and funding execution is generally incorporated in

the monthly management reviews. The C-130, C-141, and TI management reviews all examine funds status in considerable detail. Though the LY monthly review does not look at funds obligations, it does contain several criteria that assess contracting performance.

Another area that receives little attention, in terms of formal monitoring, is engineering. The C-130 and C-141 management reviews contain the most thorough assessment of performance in this area. Although the WR-ALC TI management review does not look at 103 (engineering change) requests, it does examine first article processing time. Other management indicators that are worthy of mention include aircraft depot inventory, "G" condition assets, and critical items. In various formats and levels of detail, the C-130, C-141, WR-ALC TI, OO-ALC LI, and SM-ALC LA directorates examine the material support status for parts shortages that are causing delays in the maintenance repair cycle. "G" condition assets refer to those items awaiting parts. Thus, this criterion may help determine where problems with material support and excess WIP inventory reside.

Another indication of excess WIP is aircraft depot inventory. This criterion is a measure of the number of aircraft that are in depot status at any one time. All aircraft directors realize that decreasing the number of aircraft at the depot can help reduce depot maintenance flow days. However, only the C-130 and C-141 directorates are formally tracking this indicator. Table V-6 lists several

Table V-6

Cross-Case Comparison of Commonly Used Management Indicators

Management Indicator	WR-ALC				OO-ALC		SM-ALC		
	C-130	C-141	LY	TI	LA	LI	LA	LI	TI
Production (MISTR or Aircraft)	X	X	X	X	X	X	X	X	X
Flow Days (*Schedule Conformance)	X	X	X	X	X		*		
Aircraft Depot Inventory	X	X	N/A	N/A		N/A		N/A	N/A
"G" Condition Assets		X	X		N/A		N/A		
Critical Items (*Top MICAP Items)	*	*		X		X	X		
Contracting Process Days	X	X	X						
103 Engineering Change Requests	X	X						X	
Overtime	X	X	X	X	X		X	X	X
Customer Reported Defects	X	X	X	X	X	X	X	X	X

X = Indicator is used by at least one division in that directorate

of the ALCs' more credible management indicators and also denotes the organizations in which they are used. Of course, other indicators like OPMD, sick leave, and manpower utilization are widely used, too. However, because these criteria tend to conflict with, or are only marginally related to, AFLC goals and objectives, they have not been included in Table V-6.

System Constraints

For the last research question, a summary table of core problems and an overall ECE diagram for AFLC depot maintenance were developed. Table V-7 lists the core problems identified in the ECE diagrams for C-130, C-141, F-4 and F-16, and F-111 and A-10 depot maintenance. Of course, C-130 and C-141 depot maintenance is performed at WR-ALC, while OO-ALC and SM-ALC are responsible for F-4 and F-16 and F-111 and A-10 depot maintenance, respectively. The first seven problems shown in bold print were selected for inclusion in the overall ECE diagram. Though some of these problems were particularly apparent at only one or two organizations, they are prevalent at all the depots and have a significant impact on depot maintenance performance. Similarly, two of the latter five problems - restrictive contract laws and the need to establish repair budgets well in advance of repair needs - also exist at all the ALCs but were not considered critical enough to include as core constraints in the ECE diagram for AFLC depot maintenance. On the other hand, while the lack of systematic procedures,

Table V-7.

Summary of Core Problems Identified at WR-ALC, OO-ALC, and SM-ALC

Core Problem	**C-130**	**C-141**	**OO-ALC**	**SM-ALC**
Key indicators in aircraft & commodities differ	X		X	X
G019 & D041 data outdated	X	X		
Future budgets based on past expenditures	X			
Restrictive personnel policies	X		X	X
Budget reduction policies	X		X	X
Scheduling practices and policies		X	X	X
Training policies		X		
Restrictive contract laws	X			
Project management not used for planning aircraft repair		X		
Repair budgets must be set well in advance of repair needs		X		
Contract engineering data on wheels and brakes is proprietary			X	
Procedures for physical routing of parts through TI not well established				X

Notes:

X = Problem was identified at this organization or depot

Bold print = Problem was included in the ECE diagram for AFLC depot maintenance

like project management, for planning aircraft repair and difficulties with the physical routing of parts may exist at more than one ALC, each of these problems was specifically identified as a constraint to depot maintenance by managers in only one organization. Finally, because the TRC for landing gear is at OO-ALC, the remaining problem regarding proprietary engineering data on wheels and brakes is unique to this depot.

The ECE diagram for AFLC depot maintenance is displayed in Figure V-44. To aid the reader's understanding, the blocks in the diagram have been numbered. Throughout the discussion, these numbers will be shown in parentheses following the appropriate subject or block topic. This diagram summarizes the constraints and undesirable effects that were the most critical and most prevalent in the organizations examined in this study. It includes the first seven problems listed in Table V-7 and an eighth constraint related to the use of standard cost procedures. Throughput (T), inventory (I), and operating expense (OE) are the three criteria used to measure AFLC depot maintenance performance. As this diagram illustrates, excessive inventory (I), increased operating expenses (OE), and reduced throughput (T) can be traced to the following core constraints, or problems: emphasis on different performance indicators by the aircraft and commodities directorates (1), invalid data from the G019 and D041 systems (24), budgets based on past expenditures (37), restrictive personnel job

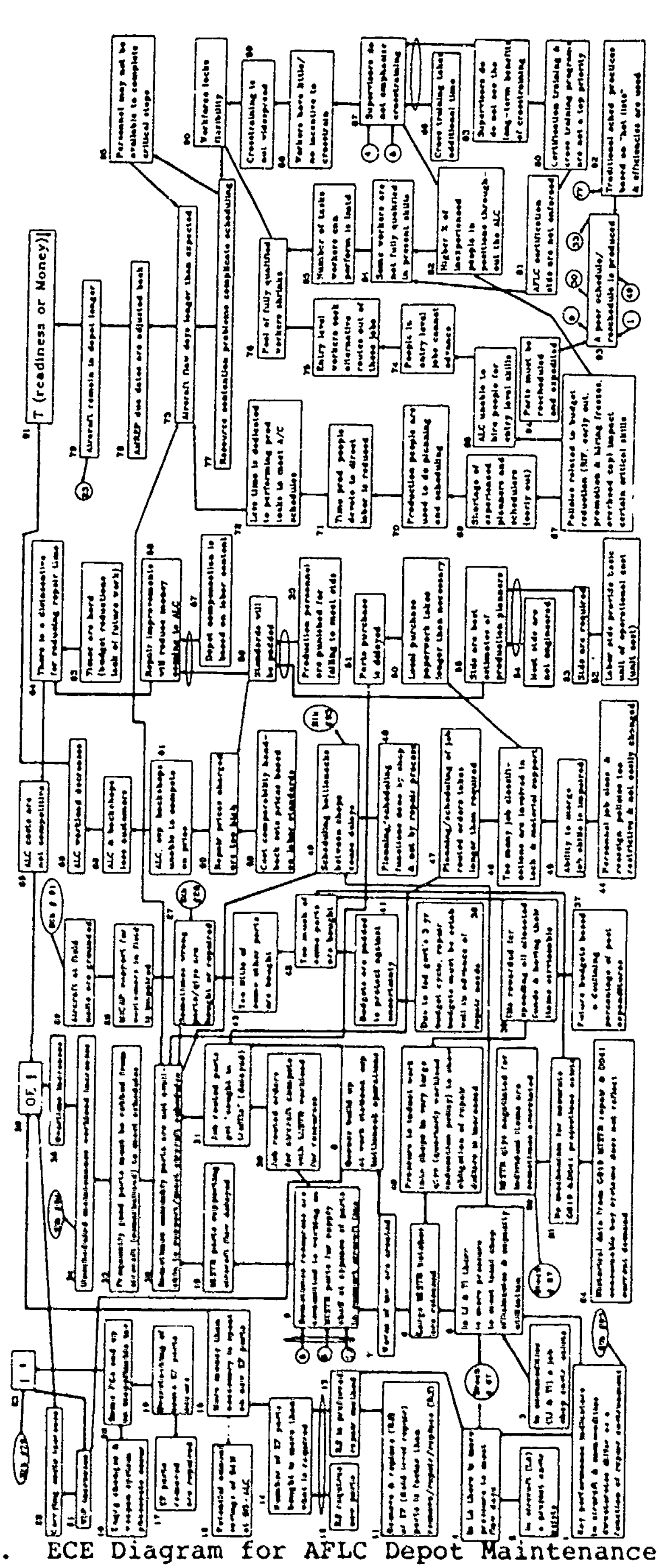


Figure V-44. ECE Diagram for AFLC Depot Maintenance

classification and reassignment policies (44), standard cost procedures (52), policies related to defense budget reductions (67), training programs receiving a low priority (80), and traditional efficiency-based scheduling practices (92). The consequences of each of these core problems will now be examined.

Differences in aircraft and commodities performance indicators (1) stem from differences in repair environments. In aircraft (LA) a project environment exists (2), while in commodities (LI and TI) a job shop environment prevails (3). Consequently, in LA more pressure is placed on meeting flow days (4), while in LI and TI more pressure to meet local efficiencies and achieve utilization targets exists (5). This emphasis on efficiencies (5) causes large MISTR batches to be released to the shop floor (6), which creates huge waves of inventory (7). As a result, sometimes resources are committed to working on MISTR parts for supply at the expense of parts to support the aircraft line (9), which causes MISTR parts that support aircraft to be delayed (10). Delays in MISTR parts (10) cause assembly parts to be unavailable to support aircraft schedules (32). Consequently, often good parts must be robbed from aircraft (33), causing unscheduled maintenance to increase (34). More unscheduled maintenance leads to more overtime (35), which results in higher operating expenses (36).

The fact that job routed orders compete with MISTR workload for resources (30) means that job routed parts

sometimes get delayed (31), which causes assembly parts to be unavailable to meet aircraft schedules (32). The waves of inventory (7) also cause queues to build up at workstations (8), which results in higher WIP (21) and higher overall inventory (23). Increases in WIP (21) also increase carrying costs (22), resulting in higher operating expenses (36). Finally, the pressure in LI and TI to meet efficiencies (5) also results in scheduling bottlenecks between backshops (49), causing assembly parts to be unavailable to support aircraft schedules (32). Moreover, this pressure (5), coupled with the release of large MISTR batches (6) <u>and</u> reductions in depot throughput (91), sometimes causes resources to be committed to working on MISTR parts for supply at the expense of parts to support aircraft (9). The fact that job routed items compete with MISTR workload for resources (30) also causes backshop resources to be improperly committed (9). As a result, MISTR parts are delayed (10), and assembly parts are unavailable to support aircraft schedules (32). Lack of assembly parts (32) causes aircraft flow days to be longer than expected (73).

On the other hand, the pressure to meet flow days in LA (4) causes removal and replacement to be the preferred repair method for parts coded for field level repair (XF parts) (13). Removal and replacement (13) is also preferred because it is faster than the removal, repair, and replacement of these parts (11). Given that (13) is

generally true <u>and</u> the fact that removal and replacement requires new parts (12), then the number of XF parts bought is more than what is required (14), which means that more money than necessary is spent on new XF parts (15). The fact that OO-ALC's managers estimate that $4 million could be saved annually at their depot by repairing more XF parts (16) verifies the assertion in (15). XF parts removed are eventually repaired (17), so overstocking of some XF parts occurs (19). If overstocking occurs (19), then some finished goods end up as inapplicable inventory (20), causing overall inventory to increase (23). Inapplicable inventory (20) also increases carrying costs (22), resulting in higher operating expenses (36). Engineering changes and weapon system phaseouts (18) are also causes of inapplicable inventory (20).

Quarterly or large batch workload induction policies (40) are a protection against uncertain demand, which is exacerbated by the core problem in block 24. Data from the G019 MISTR repair and D041 consumable buy systems is often six to nine months old and does not reflect current demand (24). Thus, no mechanism for accurate G019 and D041 projections exists (25), and MISTR quantities negotiated for individual items are sometimes overstated (26), resulting in wrong quantities of parts being repaired (27). Also, because no mechanism for accurate D041 projections exists (25), too much of some parts (42) and too little of some other parts (43) are sometimes bought, resulting in the

wrong parts or the wrong quantities of parts being bought (27). If the wrong parts are bought or repaired (27), then sometimes assembly parts are not available to support the depot's aircraft schedules (32), which causes aircraft flow days to be longer than expected (73). In addition, because the wrong parts are purchased or repaired (27), MICAP support for customers in the field is impaired (28). As a result, aircraft at field units are grounded (29) and system throughput declines (91).

The third core constraint is the basing of future budgets on a declining percentage of past expenditures (37). Due to this problem (37), item managers are rewarded for spending all their allocated funds (39). Consequently, item managers tend to pressure maintenance to induct work in large quantities (40), which causes large MISTR batches to be released to the shop floor (6). Because item managers are measured on program execution (spending of allocated funds)(39), too many of some parts are bought (42), which may result in inapplicable inventory (20). Finally, the fact that repair budgets must be established well in advance of repair needs (38) causes budgets to be padded to protect against uncertainty (41). Padded budgets (41) cause too many of some items to be purchased (42).

The fourth core problem, traditional scheduling practices (92), results in poor schedules and rescheduling (93). Poor schedules (93) are also the result of efficiency-based performance criteria (1), scheduling

bottlenecks between backshops (49), and the expediting and rescheduling of parts (94). Scheduling bottlenecks (49) stem from the fact that planning and scheduling of backshop repairs are done by shop instead of by process (48). As discussed in the F-16 case, poor schedules (93) result in two ECE loops - one in the aircraft repair line and the other in the backshops. For aircraft repair, poor schedules sometimes cause parts cannibalization (33), which increases unscheduled maintenance (34). Unscheduled maintenance (34) leads to parts expediting (94), which necessitates rescheduling (93). In the backshops, poor schedules cause resources to be committed to working on MISTR parts for supply at the expense of parts for aircraft (9) and result in insufficient attention being devoted to job routed work orders, which must compete with the MISTR workload for resources (30).

The fifth core problem, restrictive OPM (Office of Personnel Management) job classification and reassignment policies (44), hampers managers' efforts to merge job skills (45). Consequently, too many job classifications are involved in technical and material support (46). Therefore, planning and scheduling of job routed orders takes longer than required (47) and ultimately job routed parts get delayed (31). Also, because too many job classifications are involved in technical and material support (46), local purchase paperwork takes longer than necessary (50), which delays parts purchases (51). If purchased parts are delayed

(50), then sometimes assembly parts are not available to support aircraft schedules (32).

A sixth core constraint concerns the standard cost accounting system and the use of unit costs and product costs based on labor standards (52). Due to this system (52), the use of labor standards is required (53). The requirement for standards (53), plus the fact that most standards are not engineered (54), results in most standards being the best estimates of planners (55). Because standards are generally best estimates (55) <u>and</u> production personnel are punished for failing to meet standards (30), standards tend to be padded (56). Padding of standards (56) and the fact that the cost comparability handbook sets prices based on labor standards (59) cause the repair prices charged to be too high (60). As a result, if the depots, and the backshops in particular, are unable to compete on price (61), then these organizations ultimately lose customers (62). This loss (62) causes the ALC workload to decrease (66) and ultimately throughput (91) to decline. In addition, if padding of standards exists (56) <u>and</u> depot compensation is based on labor content (57), then repair process improvements will actually reduce the money coming to the depot (58). Due to this reduced revenue (58), and the current climate of defense budget reductions and lack of future work (63), there is actually a disincentive for reducing repair time (64). This disincentive (64) causes

ALC costs to not be competitive (65) and operating expenses to increase (36).

A seventh core problem involves budget reduction policies, such as the reductions in force (RIFs), early outs, the AFLC 27 percent overhead cap, and the promotion and hiring freezes, and their impact on certain critical skills (67). Because of the hiring freeze (67), the ALCs are unable to hire people for entry level skills (68). Consequently, people in entry level jobs cannot advance (74) and begin to seek alternative routes out of these jobs (75), causing the pool of fully qualified workers to shrink (76). The shrinking pool of workers (76) results in a workforce that lacks flexibility (90), which leads to resource contention problems that complicate scheduling (77). Due to these problems (77), personnel may not be available to complete critical steps (95), which causes aircraft flow days to be longer than expected (73). Furthermore, the overhead cap and the early out offerings (67) have resulted in a shortage of experienced planners and schedulers (69). Due to this shortage (69), production employees are used to do planning and scheduling (70), causing the time that production personnel devote to direct labor to be reduced (71), which results in less time being dedicated to performing production tasks to meet aircraft schedules (72). Consequently, aircraft flow days are longer than expected (73).

The last core constraint concerns the low priority afforded to certification training and cross training programs (80). Because certification training is not a top priority (80), AFLC certification standards are not enforced (81). Therefore, some workers are not fully qualified in their present skills (84). Thus, the number of tasks that workers can perform is limited (85), causing the pool of fully qualified workers to shrink (76). The higher percentage of inexperienced personnel found in ALC positions (82), which stems from the budget reduction policies (67), has also resulted in some workers not being fully qualified in their present skills (84).

Because cross training is not a top priority (80), supervisors do not see the long-term benefits of cross training (83). This fact (83), plus the fact that cross training takes additional time (86), means that supervisors do not emphasize cross training (87). The fact that the workforce is much more inexperienced than in the past (82) also causes supervisors not to emphasize cross training (87). Finally, if pressure to meet flow days and AMREP schedules exists in LA (4), then aircraft supervisors will not emphasize cross training (87). Likewise, if pressure to meet efficiencies exists in LI and TI (5), then backshop supervisors will be reluctant to emphasize cross training (87). Therefore, workers will have little incentive to cross train (88), so cross training will not be widespread (89). If cross training is not widespread (89), then the

workforce lacks flexibility (90). The lack of flexibility in the workforce (90) results in resource contention problems that complicate scheduling (77). Due to resource contention problems (77), personnel may not be available to complete critical steps (95), causing aircraft flow days to be longer than expected (73), which results in AMREP due dates being adjusted back (78). Thus, aircraft remain in the depot longer than anticipated (79), causing aircraft depot inventory to increase (23). More importantly, ultimately throughput declines both in terms of sales revenue and of weapon system readiness (91).

In summary, the use of efficiency-based performance criteria, the DOD budget process and policies related to budget reduction, traditional scheduling practices, standard cost accounting procedures, OPM personnel policies, and AFLC training policies combine to ultimately result in higher inventories and operating expenses and lower throughput for AFLC depot maintenance. Efficiency criteria, historical G019 and D041 data, the basing of budgets on past expenditures, efficiency-based scheduling policies, and restrictive job classification and reassignment policies lead to actions which cause inventories to increase and assembly parts for aircraft schedules to be delayed and not available when needed. Standard cost accounting procedures cause the ALCs to charge too much for repairs, which results in higher operating expenses, lost customers, and decreased future throughput. Policies related to budget reductions

and training cause resource contention problems. Resource contention problems and the unavailability of assembly parts cause aircraft flow days to be longer than anticipated. Consequently, customer delivery dates for aircraft are slipped, causing both depot revenues and weapon system readiness to decline.

Of the eight core constraints shown at the bottom of Figure V-44, five (37, 44, 52, 67, 80) may be categorized as managerial policy constraints and three (1, 24, 92) as logistical constraints. However, constraints (1), (24), (37), (52), (67), and (92) are largely the result of management policy and a total reliance on standard cost accounting procedures. The remaining two constraints (44, 80) stem from AFLC and DOD personnel policies. Thus, all eight constraints may be traced to two root problems not shown in Figure V-44 - standard cost accounting philosophy and federal government personnel policies. To adequately describe the underlying causes of these root problems, though, would have required expanding the scope of this dissertation above depot level to AFLC headquarters and the highest levels in DOD.

The top managers in AFLC and DOD depot maintenance have traditionally been primarily concerned with maintaining high efficiency and capacity utilization standards. In fact, customer due dates are sometimes sacrificed trying to satisfy efficiency ratings rather than customer needs. Additional delays, especially for job routed items, can be

traced to a shortage of experienced planners and schedulers and an excessive number of job classifications in the material and production support process. Within the last year, a cap on overhead and the early retirement of a considerable number of planners and schedulers have resulted in fewer knowledgeable people in these functions at all the ALCs. To eliminate job duplication and make more efficient use of a smaller pool of experienced production and material support personnel, some managers are attempting to combine various job skills. The lack of flexibility in OPM job classification rules, however, makes skill merging difficult. Furthermore, because union rules discourage skill broadening and employees are most comfortable in their own area of expertise, cross training has not proceeded as fast as top management hoped it would. Finally, traditional organizational structures also act as barriers to system performance. In many AFLC divisions, planners and schedulers are still organized by shops, rather than by repair processes. This functional organization contributes to the creation of "artificial" bottlenecks in the scheduling process.

Difficulties in the scheduling process may also be traced to AFLC's remanufacturing environment and pressures to meet local efficiencies. The highly non-deterministic nature of depot remanufacturing and the differences in key performance indicators between the aircraft and commodities directorates hinder synchronization of backshop component

repair schedules and aircraft repair schedules. The backshops' primary task is to repair certain quantities of MISTR items by the end of the quarter, so their main concern is meeting efficiencies, rather than due dates. The aircraft repair line, on the other hand, is under much more pressure from their customers to meet due dates. Overall, AFLC depot maintenance may be characterized as a series of disassembly and reassembly operations for several end items (aircraft) and a multitude of component parts. In such an environment, accurate job priorities are difficult to establish. Typically, parts that are removed from an aircraft last are the ones that must be installed first during reassembly. Although AMREP due dates are considered when assigning component part due dates, generally no distinction, in terms of required reinstallation order, is made among several component parts with the same due dates. Therefore, assembly parts are not always available when needed. As a result, job priorities must constantly be revised, rescheduling is the norm, and backshop first-line supervisors tend to rely on the daily "hot list" for priority control. This day-to-day "firefighting" ultimately stems from the conflict between the aircraft repair line's throughput-oriented project management environment and the backshops' efficiency-driven job shop operations. To reduce firefighting activities and improve assembly parts availability, the depots need to develop a scheduling

mechanism for linking backshop repair of component parts with aircraft repair and AMREP due dates.

For AFLC to effectively compete, it must increase workforce flexibility, reduce job duplication, and improve shop floor scheduling and production practices. While restrictive personnel policies, outdated cost accounting procedures, and outmoded data systems must be changed for depot maintenance performance to improve in the long term, in the short term many benefits to system performance could be achieved simply through better shop floor scheduling and workload induction practices. Both proper management of bottleneck operations and limiting the release of parts to the shop floor would speed process flows in many AFLC shops. Unfortunately, workload induction tends to be driven by DOD budget realities and by an AFLC performance measurement system that rewards the achievement of high efficiencies. Nonetheless, the few AFLC managers, like those at OO-ALC's aircraft directorate, SM-ALC's pneudraulics division, and WR-ALC's avionics directorate, that have begun to deemphasize efficiency indicators have been able to achieve reductions in inventory and operating expenses and improvements in throughput.

CHAPTER VI

MODEL DEVELOPMENT AND CONCLUSIONS

Introduction

The purpose of this dissertation was to study the performance measurement systems of the Air Force Logistics Command's aircraft repair depots in order to develop guidelines concerning the congruency of AFLC goals and depot objectives, the importance of certain competitive edges, the performance criteria appropriate for AFLC depots, and AFLC system constraints. In addition, a prescriptive model of performance criteria that are appropriate for these depots was to be developed. The first portion of this chapter presents twenty guidelines in the areas of AFLC goals and depot objectives, competitive edges, performance criteria, and system constraints as well as a depot maintenance performance model. The remainder of the chapter contains the dissertation summary and conclusions, the limitations of the study, implications of the study for practitioners and researchers, and suggestions for further research. Table VI-1 summarizes the guidelines developed for each research question. These guidelines will now be examined in detail.

Table VI-1.

Summary of Guidelines

AFLC Goals and Depot Objectives
1. A necessary condition of AFLC should be to maintain weapon systems readiness.
2. AFLC goals and depot objectives should address the competitive edges.
3. Depot objectives should ensure that performance is driven to achieve customer satisfaction.
Competitive Edges
4. Competitive edges for AFLC are similar to those on which for-profit companies compete.
5. Performance criteria used to measure performance on the competitive edges vary from function to function.
Performance Criteria
6. Performance criteria should show the impact of depot maintenance performance on aircraft operational readiness.
7. Performance criteria should focus on horizontal linkages.
8. Performance criteria should be consistent across organizational levels and functions.
9. AFLC should make time the primary metric of its performance measurement system.
10. Performance criteria should measure the competitive edges of quality, cost, and delivery.
11. Cost measurement at division and branch levels should focus on nonfinancial criteria.
12. Attitudes regarding defect reporting must be corrected.
13. AFLC needs to differentiate between order winning and order qualifying criteria.
14. The AFLC performance measurement system should be based on the principle of management by exception.
15. The AFLC performance measurement system should link customer expectations and operations decisions to financial results & operations decision making to customer expectations.
System Constraints
16. AFLC should initially concentrate on streamlining and synchronizing process flows.
17. AFLC should focus process improvement on internal resource constraints.
18. Top management should concentrate on identifying policies that act as system constraints.
19. AFLC headquarters should work to change personnel, budgeting, and cost accounting policies.
20. Depot maintenance data systems should be integrated and updated so information can be obtained from one or a few systems on performance in many areas.

Guidelines

AFLC Goals and Depot Objectives

1. **A necessary condition of the AFLC, a nonprofit organization, should be to maintain weapon systems readiness at or above levels specified by customer commands while staying within the command's allocated budget.**

Necessary conditions are boundaries imposed on an organization's behavior by power groups outside the organization (Goldratt, 1990b). The difference between a goal and a necessary condition is significant. For example, for any organization, cash flow is a necessary condition. Although cash flow below some minimum level will eventually bankrupt an organization, cash flow above this level is not necessary. On the other hand, organizations generally try to maximize goals. The goal of profit organizations is to make more money now and in the future (Goldratt, 1990b). In contrast, the purpose of nonprofit organizations is to provide a necessary level of service. Nonprofit hospitals provide some established level of health care. Universities exist to provide a level of education which is generally prescribed by an accrediting body. As a component of the Air Force and the DOD, AFLC exists to provide a desired level of weapon systems readiness. This level is prescribed by the major commands that are AFLC's customers. The DOD defines readiness as "the ability of forces, units, weapon systems, or equipments to deliver the outputs for which they

were designed" (Moore, Stockfisch, Goldberg, Holroyd, & Hildebrandt, 1991, p. 1). Therefore, for the AFLC, weapon systems readiness is a necessary condition.

Even though operational or weapon systems readiness has traditionally been acknowledged as significantly important for AFLC and the Air Force, some AFLC managers now regard profitability as their most important goal. This change in thinking is the result of the DOD budget reductions and the increased attention by the AFLC headquarters and ALC commanders to directorate profit and loss status. Nevertheless, despite the recent emphasis on profitability, this researcher believes that a desired level of aircraft operational readiness should continue to be of significant importance to the AFLC. While budgetary considerations play a greater role in AFLC decision making today than they did a decade ago, the AFLC certainly cannct afford to sacrifice readiness at the expense of profitability. A substantial profit by a particular ALC, for instance, would mean little if the operational readiness levels of the aircraft repaired by that depot were degraded in the process.

The budget is merely a necessary condition levied on the depots by the DOD and the AFLC. Other necessary conditions for AFLC's depots include requirements for adhering to certain safety procedures in performing depot maintenance, for meeting minimum quality and maintenance standards concerning safety of flight, and for complying with contract regulations and public laws in weapon system

procurement. Failure to keep spending within the budget or to satisfy any of the other necessary conditions may restrict the AFLC's ability to achieve higher readiness. However, these conditions should not be confused with the primary necessary condition of weapon systems readiness or the means of achieving it. Although budget reductions and budget policies hamper AFLC's ability to sustain current readiness levels, making a profit should not become an end in itself. The means to attain higher readiness are to obtain improvements on the competitive edges of quality, cost, delivery, lead time, innovation, and flexibility. Accomplishing improvements on these competitive edges will enable the AFLC to achieve the desired levels (percentage) of readiness within the parameters of its budget.

2. **To achieve weapon systems readiness, the AFLC goals and depot objectives should specifically address the competitive edges on which the AFLC and its Air Logistics Centers (ALCs) compete.**

In this dissertation, goals have been defined as the desired future states which AFLC seeks to achieve. Objectives is the term used to specify the measurable targets that a depot or one of its subordinate units seeks to achieve. All directorate and division chiefs surveyed in this study believed that their depot objectives supported the AFLC goals to either a significant or a great extent. This researcher concurs with this assessment. However, the AFLC goals vaguely deal with just three topics - people, quality,

and user support - and may not be suited to an environment of competition with the private business sector. Consequently, the organizations examined in this study all found it necessary to address additional issues essential to mission accomplishment.

Cox and Blackstone (1990) note that strategic objectives should be established for each competitive edge that customers consider to be important. This dissertation has defined a competitive edge as any element on which an organization can attain a competitive advantage. The additional objectives addressed by the AFLC managers surveyed in this study were directly related to the competitive edges that they deemed to be the most critical for accomplishing depot maintenance - quality, cost, and delivery. For example, WR-ALC directorates tended to specify cost reduction and on-time delivery in their unit objectives. Two key objectives for the OO-ALC and SM-ALC organizations, customer satisfaction and being competitive, incorporated subobjectives on timeliness and cost reduction.

The depots' customers, like those of any private firm, expect the AFLC to deliver a quality product at the least price. With the mandating of competition by DMRD (Defense Management Review Decision) 904, the customers from the using commands have the freedom to give their depot repair business to whomever they please. As a result, the ALCs realize that they must tailor their objectives around the elements that their customers deem important - quality,

price, and delivery. Moreover, the AFLC recognizes that to compete successfully with other service depots and with private industry it must change its strategy, that is, change the way it does business. The current AFLC goals discuss quality in the most generic terms, fail to address cost reduction, and address delivery only indirectly via the customer satisfaction goal.

On July 1, 1992 AFLC will cease to exist and will become part of the new Air Force Materiel Command (AFMC). Fortunately, the vision and goals of the AFMC are more realistic and business oriented. The AFMC vision is to be an integrated team, delivering and sustaining the best products for the world's best air force. The AFMC goals, as outlined in a recent briefing by Brigadier General Patricia Hinneburg (November 2, 1991), are as follows: (1) Satisfy customer needs in war and peace; (2) Enable people to excel; (3) Sustain technological superiority; (4) Enhance the excellence of business practices; and (5) Operate quality installations. While these goals do not specifically address quality, cost, and delivery, these elements are indirectly addressed by the fifth, fourth, and first goals. The AFMC goals are oriented more toward competition and cover a wider range of activities vital to the command's mission. Consequently, the depots should more easily be able to develop objectives that support these goals and relate to the competitive edges.

Of the depot objectives reviewed in this study, the ones for SM-ALC (refer to Figure IV-65) most closely reflect the AFMC goals and most specifically address the competitive edges of quality, cost, and delivery. These objectives are also the only depot objectives in this study that meet the dissertation definition of an objective. The first SM-ALC objective on cycle times and defect rates is directly tied to delivery and quality, and the third SM-ALC objective on logistics support cost obviously addresses cost. In summary, the depot objectives should be specific enough that the center's directorates recognize where to concentrate improvement efforts.

To achieve global improvements in quality, cost, and delivery, organizations can often use the other competitive edges of lead time, flexibility, and innovation. For example, reductions in operations lead times at constraint resources typically translate to a higher percentage of on-time delivery of finished goods, such as repaired aircraft. Shorter lead times also make it easier to identify the cause of quality problems and prevent them from recurring. In turn, reductions in scrap and rework can decrease operating expenses and result in increased throughput. In addition, reduced levels of scrap and rework can make supervisors less reluctant to reduce high work-in-process inventories (Umble & Srikanth, 1990).

Product and process flexibility and innovation may also improve quality, reduce cost, and aid delivery. Dixon et

al. (1990) define manufacturing flexibility, or responsiveness to change, in terms of competitive advantage. Their flexibility framework has eight dimensions associated with quality, product, service, and cost. Some of these dimensions will now be briefly described. Quality flexibility allows a firm to accommodate variations in the quality of purchased materials and to make products with different quality requirements. For AFLC depot maintenance, this type of flexibility is especially applicable to the repair of exchangeables. Modification flexibility refers to the ability to modify existing products, and delivery flexibility is defined as the "ability to change the current production and/or delivery schedule to accommodate unanticipated needs" (Dixon, Nanni, & Vollmann, 1990, p. 152). These last two types of flexibility are particularly critical for aircraft depot repair. Finally, cost factor flexibility may be considered the ability to alter the mix of materials, labor, and capital used in the production or repair process and, as defined by Dixon et al. (1990), is closely associated with technological innovation. Obviously, this flexibility dimension is important for AFLC's technology and industrial support (TI), aircraft, and commodities directorates.

3. **Depot and directorate objectives should ensure that directorate performance is driven in the direction of achieving customer satisfaction and the other AFLC goals.**

According to Hall et al. (1991), in today's competitive manufacturing environment "customer satisfaction is paramount" (p. 3) and improvement programs should emphasize quality, the development of people, and the compression of lead times for all activities. General Electric considers the critical success factors for customer satisfaction to be quality, price, and dependability (Hall, Johnson, & Turney, 1991). Hall et al. (1991) regard dependability as being synonymous with on-time delivery. Cox and Blackstone (1990) consider customer satisfaction to be determined by the degree to which a product meets or exceeds a customer's expectations on each of the competitive edges. Therefore, for this dissertation, customer satisfaction is defined as the timely delivery of a high quality product at a competitive price.

While customer satisfaction is typically viewed as a worthy goal by AFLC supervisors at all levels, the terminology and assumptions underlying several of a depot's or a directorate's objectives may greatly impact how well this goal is achieved. For example, the SM-ALC subobjective on developing specific process unit cost targets could ultimately drive depot and directorate performance in the wrong direction. The standard cost system is a local, rather than a global, cost system which attempts to reduce the costs of isolated processes and products. Also, standard cost procedures are based on several invalid assumptions, of which the allocation of indirect costs, or

overhead, according to direct labor cost is the most detrimental in terms of accurately assessing the impact of local actions on system performance (Umble & Srikanth, 1990).

For instance, in an effort to reduce process unit costs, a directorate might approve the purchasing of an additional machine for a particular operation on the basis of payback period. If the labor content of this particular operation is reduced, then workers will probably be removed from this operation. However, unless these workers are fired, labor costs for the whole organization will not have been reduced. Moreover, indirect costs do not disappear. Because of the way in which overhead is allocated, some of the indirect costs formerly assigned to this particular operation will now be shifted to another process or product group. As a result, the product costs of all products not processed through this operation will increase (Umble & Srikanth, 1990). Thus, this example illustrates how local unit cost reductions do not necessarily translate into global cost reductions.

Besides addressing cost, the depot objectives pertinent to the competitive edges of quality and delivery need to be developed. The wording of these objectives is also important. For instance, objectives dictating the elimination of all WIP and the implementation of SPC at all workstations would probably have a negative effect on system throughput and operating expense. To maintain a synchronized flow of parts, small buffers of WIP are still

needed at the internal resource constraints and at the assembly points over which constraint parts pass. These assembly buffers consist of nonconstraint parts to ensure that constraint parts are never delayed (for lack of non-constraint parts) (Fogarty, Blackstone, & Hoffmann, 1991).

In regard to quality control techniques, the use of SPC at an internal resource constraint will have a greater, more immediate impact on throughput than the implementation of SPC at a nonconstraint operation. However, SPC is not the only technique available for quality control and improvement. Too often when a process goes out of control, supervisors and workers do not try to determine how the problem that caused the process to slip out of control can be corrected. One inexpensive method that can be used to prevent errors and reduce defects is Shingo's concept of mistake proofing. Other quality control techniques include source inspection, Pareto analysis, and fishbone diagrams (Fogarty, Blackstone, & Hoffmann, 1991).

Two issues that need to be considered in developing depot delivery objectives concern due date performance and quoted lead times (Goldratt & Fox, 1986). AMREP due dates are continually adjusted, so AFLC's reported due date performance for aircraft is generally quite good. Because exchangeable repair delivery is negotiated on a quarterly basis, due date performance and quoted lead times have, until very recently, held little meaning and been of little concern to the TI and commodities directorates that repair

these items. Unfortunately, too often quoted lead times for aircraft have also been meaningless. It has not been unusual for delivery dates for aircraft undergoing PDM or depot modifications to exceed original quoted lead times by one to six months. However, the advent of competition, particularly in the exchangeable repair arena, is now making shorter and more accurate lead times essential for winning bids and retaining customers.

Figure VI-1 provides some examples of depot objectives proposed by this researcher which are related to the competitive edges of quality, cost, delivery, lead time, innovation, and flexibility and the five AFMC goals. Each objective is listed under the competitive edge to which it most directly corresponds. The first and last objectives are related to AFMC's people development goal and are means for accomplishing the command's customer satisfaction goal. The second and third objectives are directly linked to the business practice excellence goal, while the fourth and fifth objectives correspond to the customer satisfaction goal. Finally, the sixth objective on innovation relates to objectives that are part of each of the five AFMC goals of customer satisfaction, people development, technological superiority, business practice excellence, and the operation of quality installations. Of course, some of the objectives can impact more than one competitive edge. Inventory reduction, for example, not only reduces carrying costs but also often leads to better quality and on-time delivery.

Quality

Strive for the total involvement of all employees in a process of continuous focused improvement

Cost

Make the throughput (T), inventory (I), and operating expense (OE) criteria the basis for linking local operations decisions and actions to local (branch and division) and global (directorate and depot) financial results

Reduce inventory to the minimum levels required to ensure timely delivery of aircraft and exchangeables

Delivery

Deliver aircraft and job routed orders to the customer on or ahead of schedule at least 95 percent of the time

Lead Time

Improve shop flow days and aircraft flow days to levels competitive with private industry

Innovation

Implement new practices and update equipment and technology to ensure future throughput and sustain weapon systems readiness

Flexibility

Make cross training a top priority for improving workforce flexibility

Figure VI-1. Objectives Proposed by This Researcher for AFLC's Depots

Although flow days is a direct measure of lead time, flow day reduction should ultimately result in better due date performance. These objectives are more detailed than the command goals but do not provide measurable targets or target due dates. Such specificity is, in the opinion of this researcher, definitely needed for directorate objectives but is not always desirable for depot objectives.

Competitive Edges

4. **The elements, or competitive edges, on which AFLC competes are dictated by the customer and are similar to those on which for-profit companies compete.**

In his study of six world class manufacturing organizations, Lockamy (1991) found that these firms competed on the elements of quality, cost, lead time, delivery, product/ process flexibility, product/process innovation, and field service. With the exception of field service, the AFLC managers surveyed in this study believed that the elements listed above were the most critical ones for mission accomplishment. Of these six elements, AFLC managers ranked quality, cost, and delivery as the most important. Likewise, the plant and division managers surveyed by Lockamy (1991) believed these three elements, along with lead time, to be the most critical strategic objectives for their firms.

Because depot managers are not directly responsible for field service activities on aircraft, they considered field service to be irrelevant. Field service, or day-to-day

technical repair, of aircraft is performed by base maintenance personnel at the field unit to which the aircraft are assigned. At base level, replacement parts are obtained from spares in the depot and base supply systems or from cannibalization of other aircraft at the field unit. Additionally, during the first few years that a new weapon system is deployed to a field unit, several AFETS (Air Force Engineering Technical Services) representatives are usually assigned to the unit to provide technical assistance and support. A WSLO (Weapon System Liaison Officer) may also be assigned by the AFLC aircraft SPM to assist the unit with material support.

Unfortunately, few articles and books in the performance measurement literature specifically discuss how firms can better compete on the edges of cost, quality, and delivery. Several authors, such as McIlhattan (1987), Howell and Soucy (1987b), and McNair, Mosconi, and Norris (1989), have proposed cost accounting systems based on JIT practices. A number of recent theses and articles from the military sector have been devoted to q ality but have tended to focus on problems with TQM implementation. The Stalk and Hout (1990) and Blackburn (1991) works on time-based competition are probably two of the best sources on how an organization can use performance criteria to become more competitive. However, while these books demonstrate the importance of using time-based measures to reduce lead time and improve customer delivery, they do not specify what to

do in particular situations to improve performance on a competitive edge.

5. **Although AFLC managers at different organizational levels and from different organizational functions perceive the same competitive edges as being critical for depot maintenance performance, the actions taken to support these competitive edges and the key performance criteria used to measure performance on the edges vary considerably from function to function and conflict with each other.**

The root cause underlying the dissimilar actions and key performance indicators can be traced to differences in repair environments in the aircraft and commodities directorates. In aircraft organizations, where a make-to-order project environment exists, the timely delivery of repaired aircraft to field units is considered to be the prime objective. On the other hand, in organizations that repair exchangeables, a make-to-stock job shop environment based on quarterly MISTR workload negotiations exists. Although these organizations also perform job routed repairs in support of depot aircraft, the MISTR workload forms the bulk of the exchangeable workload and of the organization's income. Consequently, organizations that repair exchangeables usually consider their prime objective to be keeping supply shelves filled. Therefore, while delivery performance is of greater concern in the aircraft directorates, in commodities and TI directorates, meeting

local efficiencies and utilizing capacity to the fullest extent are typically emphasized the most.

Because job routed orders must compete with MISTR workload for resources and generally necessitate breaking setups, these orders are often delayed and sometimes unavailable to meet aircraft overhaul schedules. Until supporting directorates like commodities and TI view their primary function as filling "holes" in aircraft (MICAP orders for which aircraft at the depot or a field unit are grounded) rather than filling "holes" on supply shelves, aircraft and supporting directorates will continue to differ on the actions they choose to take to support the competitive edges. The implementation of a biweekly MISTR concept, similar to the DRIVE program used at OO-ALC's aircraft avionics repair unit, is one way to help bring aircraft and exchangeable repair actions in concert with global goals. Under a biweekly MISTR program, a two-week, rather than the current three-month, window is used for setting MISTR due dates and accomplishing MISTR repair. Other factors which should promote more of a due date performance orientation in the exchangeable repair world are the advent of competition in DOD and the education of top ALC managers in the Theory of Constraints (TOC) philosophy.

Performance Criteria

6. **Because achieving weapon systems readiness is a necessary condition for the AFLC, performance criteria used to measure AFLC depot maintenance should**

show the impact of depot maintenance performance on aircraft operational readiness.

Geisler et al. (1977) advocated an operational readiness reporting system for relating aircraft operational readiness to logistics system performance in the functional areas of maintenance, supply, and transportation. While the DOD and the Air Force use several readiness reporting systems, the Status of Resources and Training System (SORTS) is considered to be "the preeminent reflection of U.S. military readiness" (Moore et al., 1991, pp. 10-11). SORTS uses unit category levels ("C-levels") to assess a unit's ability to meet its wartime mission. Unfortunately, C-levels simply reflect the amount and condition of personnel and equipment resources that the unit possesses (Moore et al., 1991) and thus do not measure logistics performance. Moore et al. (1991) observe that C-levels are only marginally objective, comprehensive, and robust and tend to reflect inputs, rather than outputs. Output performance, of course, is the essence of the DOD's definition for readiness.

The Air Force reports the operational readiness of its aircraft by classifying not operationally ready aircraft according to the kinds of logistics action (maintenance or supply) needed to return them to operationally ready status (refer to Figure IV-1). While this reporting system provides a better link between logistics actions and readiness status reporting than C-levels, it primarily shows the impact of base-level, rather than depot-level, logistics

actions. The Weapon System Management Information System (WSMIS) implemented by AFLC in 1987 assesses the Air Force's capability to go to war by computing C-levels for supplies (Hamblin, 1990). Therefore, although this system does not directly measure the impact of depot maintenance actions on operational readiness, it does provide some connection between readiness and depot-level logistics actions, especially those of item managers. More importantly, WSMIS considers what is required to employ aircraft in contingency situations. Prior to WSMIS, this consideration had typically not been incorporated in readiness reporting systems (Geisler et al., 1977).

The relationship between Goldratt's criteria of throughput (T), inventory (I), and operating expense (OE) and the traditional indicators of net profit (NP) and return on investment (ROI) has been demonstrated by several researchers (Cox & Blackstone, 1992; Goldratt & Fox, 1986; Goldratt & Fox, 1988) and is briefly discussed in conjunction with guideline 15. This researcher believes that the throughput criterion could be the primary indicator for linking AFLC depot maintenance and weapon systems readiness. Throughput is a measure of items sold, and aircraft or exchangeables must be completely repaired and operationally ready before they can be sold. In addition, the fact that an item, particularly an exchangeable part, is sold indicates that the item is required to sustain weapon

systems readiness. Obviously, this fact assumes that the purchaser of the item is aware of the requirements needed to support readiness.

To assess the impact of errors made in depot maintenance on weapon systems readiness, the local control criteria of inventory dollar days and throughput dollar days could be used. Inventory dollar days measures the time value of inventory built ahead of time and is thus an indicator of actions that should not have been taken but were done nevertheless (Cox & Blackstone, 1992). For AFLC, this criterion indicates the inventory that is in excess of short-term requirements for sustaining aircraft operational readiness and is especially appropriate for evaluating exchangeable repair. On the other hand, throughput dollar days is particularly suited for showing the impact of late aircraft deliveries on weapon systems readiness. This criterion, which assigns to each order a dollar-time value equivalent to its selling price multiplied by the number of days the order is late, is an indicator of actions that were not done but should have been accomplished (Cox & Blackstone, 1990, 1992; Goldratt & Fox, 1988). An in-depth examination of the linkages between T, I, and OE and weapon systems readiness is beyond the scope of this research. However, the throughput, throughput dollar days, and inventory dollar days criteria appear to offer at least a partial answer to Geisler's (1977) recommendation for indicators that show the cause and effect relationships

between operational readiness and logistics system performance.

7. **Performance criteria for AFLC depot maintenance should focus on horizontal linkages and work flows to help AFLC managers evaluate organizational progress toward the achievement of command goals and depot objectives.**

According to Cox and Blackstone (1990), an organization's performance measurement system should incorporate operational, tactical, and strategic goals. Vollmann (1989) observes that such a system should be tied to a firm's strategies and evolve as strategy changes. Goldratt and Fox (1988) point out that performance measurement systems at a firm's operational, tactical, and strategic levels should be designed to allow managers at these levels to make decisions that drive the firm to achieve its long-range goals. In their study of management indicators used by SM-ALC's materiel management directorate, Allen and Linteau (1980) recommended several indicators that they believed were more useful for decision making at the strategic (directorate) level and better supported the directorate's objectives. A number of supervisors interviewed in this study, like the WR-ALC TI director and OO-ALC's landing gear division chief, recognized that efficiency indicators were detrimental to the achievement of customer satisfaction and delivery objectives.

Figure VI-2 is an adaptation of the SMART (Strategic Measurement Analysis and Reporting Technique) hierarchy

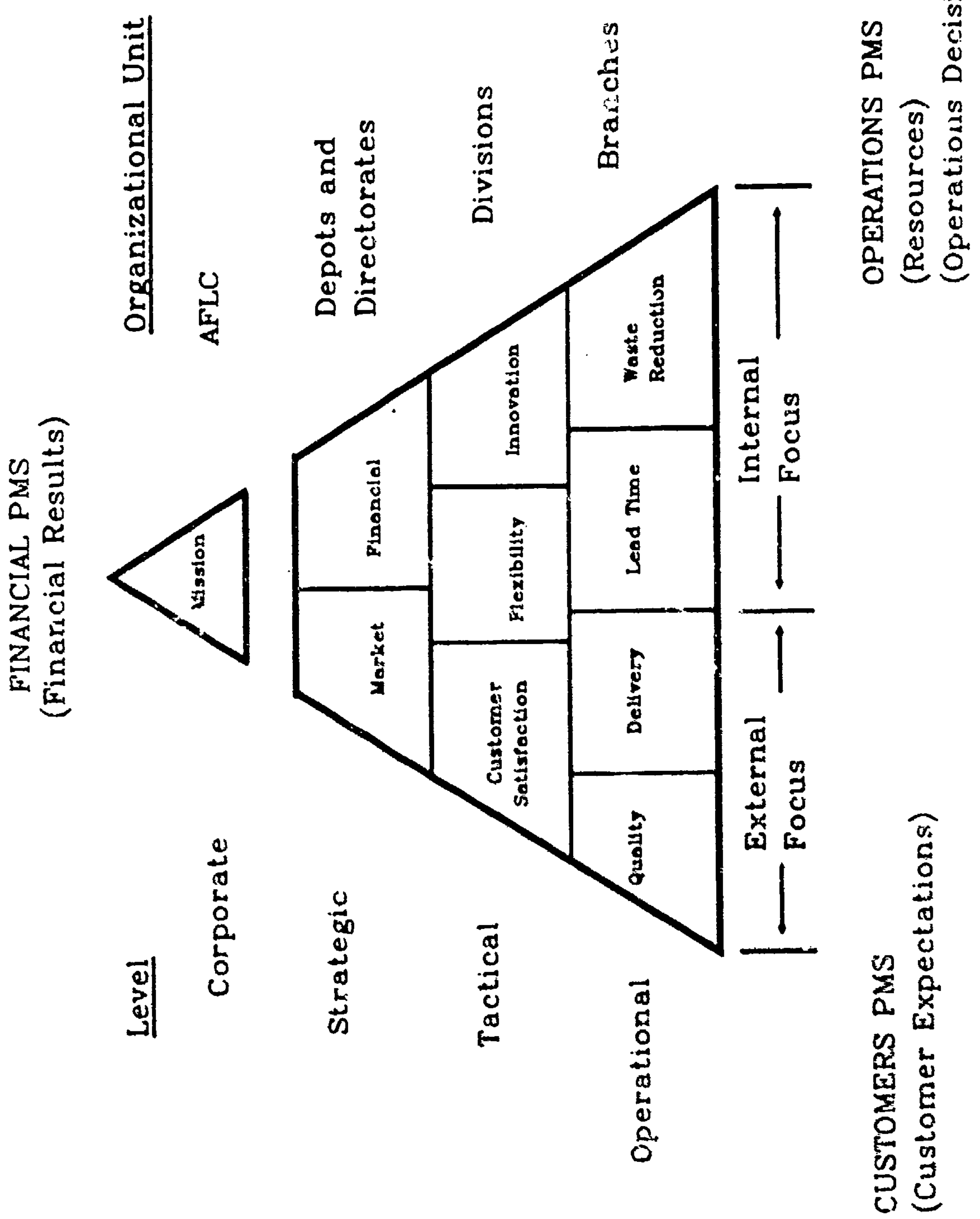


Figure VI-2. Performance Measurement Systems and Performance Measurement Hierarchy for AFLC Depot Maintenance

developed at Wang for linking operational performance criteria to strategic goals and business objectives (Dixon, Nanni, & Vollmann, 1990). This figure also includes the three performance measurement systems contained in Cox and Blackstone's (1992) performance measurement network for organizations. These systems will be discussed later in this chapter. At the top of the pyramid are the AFLC goals, which express the command's mission and are equivalent to Wang's corporate vision. Beneath the AFLC goals, at depot and directorate levels, are the strategic objectives for the marketplace and financial solvency. Examples of strategic objectives are OO-ALC's objective to be the supplier of choice and its aircraft directorate's objective to develop competitive strategies. Strategic objectives lead to tactical and operational objectives for the various divisions and branches in a center's directorates. The tactical objectives in Wang's SMART hierarchy are customer satisfaction, flexibility, and productivity; Wang's operational objectives are quality, delivery, process time, and waste.

For AFLC depot maintenance, this researcher believed that the six competitive edges ranked by depot managers in this study were appropriate objectives for linking tactical and operational performance to strategic objectives at directorate and depot levels. Therefore, for the hierarchy in Figure VI-2, innovation replaces productivity, lead time replaces process time, and waste reduction equates to cost

(reduction). At the operational level, quality and delivery objectives and performance criteria focus externally on customer expectations regarding quality and delivery. In contrast, lead time and waste reduction objectives and criteria focus internally on the measurement of operations performance and resource consumption. At the tactical level, the focus of innovation is primarily internal, while that of customer satisfaction is mainly external. Because flexibility has several dimensions associated with quality, product, service, and cost, its focus is both internal and external (Dixon, Nanni, & Vollmann, 1990). To accomplish goals and objectives at all organizational levels, a focus on horizontal work flows is essential at the tactical and operational levels.

An example of a situation where horizontal focus is needed to achieve customer satisfaction concerns the resolution of aircraft wing crack problems. As aircraft age, cracks appear in wing spars and wing surfaces. Wing cracks are critical defects that affect flight safety and often result in the grounding of aircraft. Typically, the corrective action for these defects involves not only additional depot maintenance but also the design of engineering changes and the procurement of additional parts. To minimize the processing time required to solve this problem and return an aircraft to serviceable condition requires the cooperation of several managers across the functional boundaries of contracting product engineering,

and depot maintenance. Prior to AFLC's reorganization, these functions were each located in a separate directorate. Now, to foster cross functional cooperation and enhance customer service, they are all contained within a single directorate, such as an aircraft directorate. Of course, the new organizational structure does not guarantee that the functional silo syndrome (Hall, Johnson, & Turney, 1991) will disappear overnight, but it does make it easier to break down the vertical barriers separating various functions. Reorganization alone, without a clear definition of objectives, clearly defined local actions, and correct performance criteria, can produce disastrous results.

8. **Performance criteria for AFLC depot maintenance should be consistent across organizational levels and functions so that managers at each level and function are led to take actions and to make decisions that are consistent with AFLC goals and depot objectives instead of local optimas.**

According to McNair et al. (1989), the primary purpose of a performance measurement system is to unify an organization across various functions and levels into a single unit focusing on achieving the organization's goals. As Lockamy (1991) observes, performance measurement system information needs to be shared across functional areas and organizational levels to maintain constancy of purpose. He gives examples of several mechanisms used by world class manufacturers to accomplish performance measurement

information sharing. The most common vehicle cited by Lockamy, monthly meetings between staffs at different levels, is beginning to be employed by a few AFLC organizations. For instance, the WR-ALC LY and SM-ALC LI directors are holding regular discussion sessions with branch chiefs and first-line supervisors. First-line supervisors in SM-ALC's TI directorate attend division performance reviews. In addition, the product team concept that has recently been implemented in a number of AFLC's commodities directorates is helping to foster intra-organizational level interaction. Some cross-functional interaction is also occurring, but thus far it has typically been limited to informal interaction between directorate and division chiefs and formal interaction between ALC directors at center-level meetings and management reviews.

Several of the directors and division chiefs interviewed in this study recognized that OPMD and direct labor effectiveness have little relation to quality and delivery objectives. As a result, these managers have begun to deemphasize or eliminate the reporting of efficiency indicators. These indicators are no longer included in the monthly management reviews for the C-141 and the avionics directorates at WR-ALC and the aircraft operations and technical repair divisions at OO-ALC. At SM-ALC, the pneudraulics division chief has even eliminated efficiency criteria from the individual performance criteria for all supervisors and workers.

The blocks inside the pyramid shown in Figure VI-2 depict the competitive edges on which managers at each level should focus their improvement and performance measurement efforts. By focusing on a few edges at each level and employing performance criteria that are consistent across organizational levels, AFLC's overall goal of weapon systems readiness can be achieved. At the operational level, quality, delivery, lead time, and waste reduction are measured by the customer performance measurement system (PMS) and the operations PMS. At the tactical level, these two PMSs focus on customer service, flexibility, and innovation. Customer service incorporates concepts related to quality and delivery. Flexibility and innovation are generally means to accomplishing objectives related to the operational competitive edges of quality, delivery, lead time, and waste reduction. Timely delivery of high quality aircraft and exchangeables to field units enables AFLC to maintain weapon systems readiness levels and the Air Force to sustain aircraft operational readiness. As the pyramid clearly illustrates, only at directorate level and above does the competitive edge of cost merit substantial consideration (Cox & Blackstone, 1992; Dixon, Nanni, & Vollmann, 1990).

Inherent in the idea of consistency of performance criteria is the concept of consistency of actions and the linkage of performance criteria and performance measurement systems to the actions of management and the workforce. The

axiom, "Tell me how you will measure me, and I will tell you how I will behave" (Goldratt, 1990b, p. 26) certainly applies in many organizations, including AFLC. Dixon et al. (1990) give several examples of how action programs like JIT and TQM can provide the driving force for changing performance criteria and measures.

A situation in which performance criteria could promote actions inconsistent with depot and directorate objectives concerns the implementation of synchronous manufacturing in an AFLC backshop that repairs MISTR items. Using this approach, the shop supervisor would probably begin to induct the MISTR workload in smaller batches and on a more even basis so that work could be released to the shop floor at a rate consistent with the production pace of the shop's internal resource constraint. Eventually the supervisor might realize that indicators like direct labor efficiency were impeding continuous improvement. Hence, he or she might begin to emphasize cycle time or shop flow days. However, suppose that the key criterion for assessing item management performance continued to be program execution. In that case, the item managers for these MISTR items would want to ensure that their repair dollars were obligated as quickly as possible and would be inclined to pressure the schedulers in this shop to continue the practice of quarterly workload induction. Obviously, such large batch induction would disrupt efforts to synchronize material flow in the shop.

9. **Rather than striving to be the low-cost producer, AFLC should strive to compete on time and should make time the primary metric of its performance measurement system.**

Reducing cycle times would enable AFLC to offer shorter quoted lead times and to improve due date performance. Cycle time reduction also has a positive impact on quality and is totally consistent with AFLC's TQM philosophy. Performance criteria that are not consistent with TQM principles not only hamper TQM implementation efforts but are also counterproductive to the accomplishment of command goals and depot objectives. Stalk and Hout (1990) point out that cost-based measures actually conflict with an organization's emphasis on quality as a competitive weapon. These authors recommend that a firm should keep some cost measures in order to control expenditures but should primarily emphasize time-based measures, which tend to reinforce quality objectives. Quality measures like rework, yield, and defect rates are directly linked to overall cycle time (Stalk & Hout, 1990). Blackburn (1991) points out that time compression has its origins in the JIT philosophy. The small batches employed in JIT manufacturing mean that defects are more readily revealed and their causes more quickly isolated. In addition, by setting company goals for the reduction of throughput time and cycle time, organizations bring about better quality by forcing workers to "do it right the first time" (Schmenner, 1991).

Time-based competition is a logical extension of JIT manufacturing principles to the entire value delivery chain. Manufacturing is just one of several processes involved in the delivery of a product or service to a customer. Although there is a widespread belief that time reduction costs money, time compression actually reduces costs (Blackburn, 1991). In reality, cost that does not add value consumes most of the time in the value delivery system. Queue time in production, order coding time, and scheduling time all represent nonvalue-added costs. As a result, the reduction of time consumption in the value delivery system can substantially decrease the cost of goods sold (Stalk & Hout, 1990). Customers are often willing to pay higher prices for faster response or delivery. Consequently, time-based companies are sometimes able to command premium prices for their products or services. Other financial advantages obtained by time-based competitors include higher inventory turns, higher returns on investment, and lower product development costs (Stalk & Hout, 1990).

With the advent of competition in the DOD and the AFLC, there is an increased emphasis by AFLC's top managers on cost reduction. However, cost reduction efforts typically focus on reducing part costs per unit and product costs per unit. As previously illustrated, investment decisions and other local operations decisions based on standard cost accounting procedures often do not result in decreased operating expenses and increased throughput for the entire

organization. Until recently the ALCs enjoyed a virtual monopoly on depot repair, so they were never greatly concerned about responding quickly to their customers. Timely delivery of many component parts was typically achieved by shipping items directly from depot supply stocks. With the current emphasis on reducing inventory and operating expenses, the principal way for the depots to improve on-time delivery is to reduce repair lead times through continuous focused improvement. Besides improving delivery reliability, the depots will need to reduce quoted lead times to win bids and remain competitive. To compete effectively, these organizations will also need to become more flexible and more innovative. Flexibility is a key factor in reducing lead times. Innovation includes new ways of doing business and the timely execution of new ideas (Stalk & Hout, 1990). If AFLC is to become a time-based competitor, a major reorientation in the thinking of its managers will be required.

10. **Performance criteria for AFLC depot maintenance should measure the primary competitive edges on which AFLC managers perceive they compete - quality, cost, and delivery.**

Cox and Blackstone (1990) state that performance measures should be established for each competitive advantage considered to be important by customers. Dixon, Nanni, and Vollmann (1990) believe that a good performance measurement system is consistent with an organization's critical success

factors and should reveal how customer needs are satisfied. Various researchers stress the measurement of cost, quality, and delivery. McNair et al. (1989) believe that performance in these three areas, plus that of people, should be the focus of an organization's performance measurement system. According to Hall, Johnson, and Turney (1991), improvement should be measured in six areas - quality, dependability (i.e., due date performance or on-time delivery), resource (waste) saving, flexibility, innovation, and people development.

One tool to help ensure that performance criteria actually measure progress toward AFLC goals and cause local decisions to be consistent with depot and directorate objectives is the performance measurement hierarchy proposed in Figure VI-2. At branch level the four competitive edges of quality, delivery, lead time, and cost are evaluated. One or more criteria may be developed to measure performance on each of these edges. Quality and delivery focus externally on customer expectations, while time and waste focus on the input and processing of resources required to meet customer expectations (Cox & Blackstone, 1992). Lead time is synonymous with cycle time and is concerned with the time required to complete work from the time it is requested. Cost is considered only in the waste reduction category. The wastes that a local unit generates are the only costs over which it truly has control. Examples of waste include inapplicable and

excessive inventories, yield losses, and rejected materials from vendors (Dixon, Nanni, & Vollmann, 1990).

11. **Cost measurement at division and branch levels should focus on nonfinancial criteria concerned with waste reduction, including inventory reduction.**

Goldratt and Fox (1988) have developed a performance criterion called local operating expense to measure the operating expenses over which a local unit has control, such as material costs and any overhead for which the unit is solely responsible. Labor costs are not included, as these costs are considered to be fixed and, in AFLC, are generally controlled at directorate or depot level. For AFLC, material costs, in the form of excess raw material and WIP inventories, are unnecessarily high. Material waste, in the form of scrap and rework, certainly comprises a large amount of waste and of local operating expense. Hence, in AFLC the focus of waste reduction should be on the measurement of scrap, rework, and inventory.

Lower inventories have a positive impact on the competitive edges of quality, cost, and delivery. As Goldratt and Fox (1986) observe, lower inventories result in improved quality and quicker introduction of engineering changes. In terms of cost, less overtime is needed and less investment in equipment, especially at final operations, is necessary. Finally, lower WIP inventories result in shorter lead times, which are the key to more accurate forecasts. Shorter manufacturing or repair lead times in turn improve

due date performance and allow the firm to quote shorter lead times to customers.

12. **For current and proposed AFLC quality criteria to be effective, abuses in the Quality Deficiency Reporting (QDR) System and workforce attitudes regarding the reporting of defects must be corrected.**

Because many of AFLC's first-line supervisors and workers view quality defects as undesirable, there is a reluctance to report internal defects to management. Besides trying to "hide" internal defects, personnel sometimes encourage customers to either downgrade the severity of external customer reported defects or to not even report them. As a result, the number of quality defects for aircraft and exchangeables that are reported through the formal system to directorate level and above is unrealistically small. Not surprisingly, few AFLC supervisors, including top managers, actually believe the data on customer reported defects. Consequently, scant attention is paid to the few quality criteria that are included in directorate and depot management reviews. In contrast, all six world class manufacturing firms examined in Lockamy's (1991) study employed several quality criteria that were reported daily, weekly, or monthly.

For AFLC to compete effectively for future throughput, quality may be a necessary condition. Poor quality has been identified as the most important reason for American companies losing market share. Also, because consumers are

generally willing to pay more for quality products, higher quality can result in a higher return on investment (Fogarty, Blackstone, & Hoffmann, 1991). In summary, "truth in quality reporting" is essential if AFLC is to identify and correct quality problems and be competitive with other service depots and with private industry.

13. **To compete effectively, AFLC needs to assess how different products win orders against competitors and to differentiate between order winning criteria and order qualifying criteria.**

Order winning criteria refers to those criteria that win orders, while order qualifying criteria are those criteria that prevent a firm from losing orders and allow it to remain in the marketplace (Hill, 1989). Hill (1989) lists price, product quality and reliability, delivery speed, delivery reliability, and demand increases as typical order winning criteria. Price is cost to the customer, and demand increases are related to the competitive edge of flexibility. The relative importance of these various criteria, and whether they win or only qualify orders, depends on the product involved, the stage of that product in its life cycle, the degree of competition that exists for repair of that product, and factors in the external environment.

For example, for F-111 PDM most operational commanders might normally be more concerned about delivery reliability than delivery speed. Whether an aircraft is unavailable to a field unit for 120 or for 150 days is often not a major

issue. However, when a particular aircraft is promised to the unit on a certain date (delivery reliability), the aircraft maintenance managers generally expect it to be available for flying operations at that time. Late deliveries from depot can disrupt flying schedules and also impact required combat readiness levels. On the other hand, during Desert Shield and Desert Storm, delivery speed for F-111 PDM assumed paramount importance and became the top priority for the SM-ALC.

14. The AFLC performance measurement system should be based on the principle of management by exception and should focus on the measurement of the control points in the system.

Performance measurement researchers tend to advocate the use of a few, simple measures (Dixon et al., 1990; Maskell, 1989). One problem with AFLC's performance measurement and management information systems is that too much data is provided, creating confusion. Management by exception reporting involves collecting point and trend data from only the most critical operations and resources in the system, the control points. The control points are those operations or workcenters that regulate system throughput and due date performance. In most plants the control points include the gating operation, the internal resource constraint, any convergent or divergent assembly points, and the shipping buffer. The gating operation controls the release of material to the shop floor. Buffers are placed at the

constraint, assembly, and shipping points to protect the schedule for the constraint and promised due date delivery (Cox & Blackstone, 1990). The constraint buffer ensures that the constraint always has work. The assembly buffer stages nonconstraint parts at assembly points so that constraint parts are never delayed. Finally, the shipping buffer consists of finished products scheduled to be at shipping at any point in time (Fogarty, Blackstone, & Hoffmann, 1991).

Management by exception is based on using drum-buffer-rope (DBR) scheduling and buffer management to schedule and control the shop floor. The rate at which the system constraint consumes work is referred to as the drum. The constraint buffer is the time allowed for material to move from the gating operation to the constraint. The rope ensures that material releases are based on the rate at which the constraint consumes work (Cox & Blackstone, 1990).

For management and measurement purposes, buffers are usually divided into three fairly equal time regions (1, 2, and 3). Schedule deviations cause "holes" in the buffer whenever material that should be in the buffer is missing. Holes represent exceptions and are the only cause for management to react. Because all orders in region 1 should be present at the constraint, assembly, or shipping area, holes in this region indicate that immediate expediting is required. On the other hand, holes in region 3, where one-third of the orders should be present, require no action.

Holes in region 2, where two-thirds of the orders should be present, are the ones that should trigger exception reports. These holes reveal that material is taking somewhat too long to reach the workcenter. Pareto analysis or similar techniques can be employed to determine the reasons for these holes and the corrective actions required to eliminate and prevent them. Thus, by using buffer management, supervisors can concentrate their improvement efforts on problems that impact throughput, due date performance, and ultimately the firm's net profit and return on investment (Cox & Blackstone, 1990; Fogarty et al., 1991).

Focusing performance measurement on system control points, and on the system's constraints in particular, can aid in identifying constraints and allowing a firm to eliminate them. Lockamy's (1991) study provides an excellent example of how Northern Telecom uses an out-of-box defectivity measurement procedure to identify system constraints that inhibit product quality objectives. Similarly, to focus quality improvement efforts, AFLC's repair shops could concentrate SPC or other types of measurement on constraint operations. By employing SPC on constraint operations, the employees in the F-16 EPU (emergency power unit) shop at OO-ALC have substantially reduced rework rates and shop flow times for this item and its major subassemblies.

15. AFLC's performance measurement system should link customer expectations and operations decisions to

financial results and operations decision making to customer expectations.

Cox and Blackstone (1992) contend that effective management of an organization requires three performance measurement systems (PMSs) - financial, customer base, and operations. The prime elements of these systems are the owners, the customers, and the organizational resources. Each system has a distinct purpose. For a for-profit organization, the financial PMS evaluates progress toward the firm's goal of making money now and in the future. The customers PMS measures product/service characteristics against customer expectations on such competitive edges as price, quality, lead time, and delivery due dates. Operations manages the organization's resources and translates customer expectations into the resources requirements needed to meet or exceed these expectations (Cox & Blackstone, 1992).

AFLC has traditionally been viewed as a nonprofit organization. However, in DOD's current competitive climate, many of AFLC's top managers believe that the command's goals have now expanded beyond customer satisfaction and sustaining weapon systems readiness to include making money now and in the future. Therefore, a financial PMS, as well as a customers PMS and an operations PMS, is applicable to AFLC. In AFLC the financial PMS could be managed by the headquarters and the FM (Financial Management) directorates at each center, with financial performance reported at directorate and depot levels.

Figure IV-3 outlines six indicators which have been proposed by AFLC headquarters to replace the DDPMS measures that were recently implemented. Although these indicators are intended for use at command level, they could also be used at depot level. All units are expressed in the common denominator of dollars, and data are reported on a quarterly basis. Except for the quality indicator, these indicators are basically variations of the T, I, and OE criteria proposed by Goldratt and Fox (1988). All indicators, other than expense reduction, should drive behavior and performance in the direction of the command's goals. Computation of the expense reduction indicator incorporates inflation factors and unit product cost concepts from the standard cost accounting system. Therefore, while this indicator's definition for operating expense is valid, the way it measures expense reduction is not. To get an idea of operating expense trends, operating expense (as defined by Goldratt & Fox) could be tracked on a quarterly basis and compared to the previous quarter as well as the same quarter in the previous year.

While the level of detail and reporting frequency associated with AFLC's proposed indicators is adequate for the headquarters level, AFLC managers at lower levels would probably find performance data that are less aggregated and collected on a more frequent basis to be more useful. Hence, the performance criteria in Figure VI-4 are proposed by this researcher for use at directorate level, with data

1. Quality: Quality Improvement

Equation: Critical or Major Defects/Aircraft or 1,000 Exchangeables

Definitions: Critical Defect: A defect that results in hazardous or unsafe conditions for individuals using, maintaining, or depending upon the product or a defect that is likely to prevent performance of the tactical function of a major end item, such as an aircraft. Major Defect: A defect, other than critical, that is likely to result in failure, or to reduce materially the usability of the unit of product for its intended purpose.

2. Production: Product Generation

Equation: Throughput/Quarter

Definition: Throughput: Revenue generated by the system (either center, product directorate, or other unit) resulting from operation of the system. For the purpose of this measure, throughput is revenue earned less cost of direct materials.

3. Production: Expense Reduction

Equations:

(1) Compute the unit operating expense to produce an item during a specified base period [Base period operating expense (by item)/ Base period quantity (by item)]

Figure VI-3. Indicators Proposed by AFLC to Replace DDPMS Criteria

(2) Compute the uninflated operating expense [Unit operating expense x Current quantity]

(3) Compute the inflated expected operating expense [Uninflated expected operating expense x Inflation factor]

(4) Compute the individual operating expense index [Inflated expected operating expense/Current operating expense]

(5) Compute the composite operating expense index [Sum of inflated expected operating expense/Sum of current period operating costs]

Definition: Operating Expense: All of the expense incurred by the system in the conversion of inventory into throughput. Some categories of expense include: direct and indirect labor, indirect material and supplies, depreciation of capital assets, and rework.

4. Production: Inventory Activity

Equation: Inventory dollar days (inventory raw material value x number of days until item is sold [Goldratt, 1988]).

Definition: Inventory: All the money the system invests in purchasing things the system intends to sell. Inventory includes raw materials at the time that they are ordered from supply, WIP, and finished goods awaiting transfer to supply. It also includes the adjusted value of the

Figure VI-3. Indicators Proposed by AFLC to Replace DDPMS Criteria

repairable assets that are provided to maintenance at the time that they are placed under their control. Adjusted value is determined by subtracting the value of work to be performed on the asset from the replacement cost of the asset.

5. Production: Inventory Turns

Equation: Throughput/Average daily inventory*

6. Production: Due Date Performance

Equation: Throughput* dollar days (selling price x number of days an order is late [Goldratt & Fox, 1988]).

[*As defined in previous criteria in this figure]

Figure VI-3. Indicators Proposed by AFLC to Replace DDPMS Criteria

Quality

1. Critical/Major Quality Defects (per aircraft MDS or exchangeable product family)

2. Minor Quality Defects (per aircraft MDS or product)

Cost (budgeted vs actual comparisons apply to each indicator)

3. Throughput (per aircraft MDS or product family; includes Schedule Conformance and Material Usage)

4. Inventory (by aircraft MDS or by product)

5. Operating Expense (as defined in Figure VI-3)
   a. Overtime b. Material Waste (scrap and rework)

6. Net Profit (T - OE; by directorate)

7. Inventory Dollar Days for Finished Goods (by product), for WIP (by aircraft MDS or product), and for "G" Condition Assets

Delivery

8. Throughput Dollar Days (by aircraft MDS or by product)

Lead Time

9. Aircraft and Shop Flow Days (by MDS and by product family)

10. MICAP Hours (for top 20 critical items by weapon system)

11. Number and Age of Backorders for Priority 01-08 Requests

Innovation (by division)

12. Qualitative Narrative of New Practices and Technologies

Flexibility

13. Number and Level of Skills/Tasks to Which Personnel Are Cross Trained (by individual, by work team, and by branch)

Figure VI-4. Performance Criteria Proposed by This Researcher for AFLC Directorates

collection and reporting to be done monthly and trends to be examined quarterly. Essentially, these criteria comprise the criteria for the customers and operations PMSs. Many of these criteria have been previously defined in this study. The criteria are divided into six categories corresponding to the six competitive edges of quality, cost, delivery, lead time, innovation, and flexibility. They will be discussed in the order in which they appear in Figure VI-4.

Two criteria for measuring quality are proposed. The critical/major defects criterion is identical to the quality improvement indicator proposed by AFLC and is similar to the customer reported defects criterion that is used throughout the command. To help managers at division level and below "fine tune" quality improvement efforts, a second quality indicator for tracking minor defects is proposed. Many defects occur which are not serious enough to be categorized as major or critical but are nonetheless irritating to customers. These minor defects are reported to units via customer feedback cards (AFLC Form 424s). However, these defects are usually not reported above division level. Consequently, directors are not given an accurate picture of their organization's product quality. For AFLC to sustain quality improvement and compete effectively on quality, this researcher believes that a criterion for tracking and reporting minor quality defects is needed at directorate level and below.

To ensure that cost criteria drive directorate performance in the direction which promotes accomplishment of depot objectives, cost measurement should emphasize the assessment of net profit (NP) and return on investment (ROI), rather than unit cost and product cost. The T, I, and OE indicators defined in Figure VI-3 can be directly related to NP, ROI, and cash flow. NP equates to T - OE, and ROI is equivalent to (T -OE)/I (Goldratt & Fox, 1988). Cash flow equates to (T - OE) - change in I. T, I, and OE can be projected for each division, enabling budgeted performance to be compared to actual performance (Cox & Blackstone, 1992). In turn, as shown in Figure VI-4, more detailed criteria related to each of these indicators can be employed.

For throughput, schedule conformance and the value of raw materials consumed (versus projected) could be monitored. Schedule conformance is defined as aircraft sold versus scheduled (by MDS) and exchangeables shipped versus negotiated (by product or product family). A product or product family is defined as a group of related NSNs (national stock numbers) that constitute a similar item. For instance, though several NSNs for F-15 horizontal stabilizers exist, all F-15 horizontal stabilizers could be considered a product or product family. While aircraft sales information is readily available, obtaining data on the sales of exchangeables would entail establishing a mechanism at each field unit for tracking and reporting the

issuance, or sale, of exchangeable items to base maintenance organizations. Consequently, for exchangeables, items shipped from the depot might be a more realistic criterion.

Inventory that is stuck in the system represents items that are unavailable for sale to customers and thus are an added burden, or expense, to the organization. Categories of inventory that AFLC could monitor include aircraft in depot inventory status, raw materials, WIP, and finished goods, that is, exchangeables in supply. Some of the inventory which is the most detrimental to system performance is that in the WIP and "G" condition asset categories. WIP includes material stuck in the backshops as well as all aircraft in depot status. Excess WIP increases flow time in the shops and on the aircraft repair line. "G" condition assets represent items for which major material support problems exist.

Operating expense refers to all fixed costs, including direct and indirect labor. Though most AFLC directorates examine a multitude of operating expenses, overtime and materials waste were selected as the two expense categories on which to focus. Overtime is often an indicator of poor priority planning and of a failure to adequately buffer assembly control points. Thus, it is an unnecessary expense, regardless of whether it is attributed to direct or indirect labor. Materials waste, which includes scrap and rework, was previously discussed in conjunction with Figure VI-2. Because the reduction of scrap and rework is

important not only for decreasing operating expenses but also for improving quality, reducing disruptions in product flows, improving due date performance, and increasing throughput, scrap and rework levels should be measured. Although AFLC does not have a formal information system for tracking scrap and rework, manual systems for monitoring these levels of waste could be established. For example, supervisors might log the number of times various end items require rework and identify the causes of rework. Finally, because profitability has become so important in AFLC, a net profit criterion for use at directorate level has been proposed. Throughput (T) equates to the revenue from items sold (selling price - variable expenses), and operating expense (OE) is defined as it was in Figure VI-3.

Another criterion that can be used to monitor costs, specifically inventory carrying costs, and motivate managers to reduce inventory is inventory dollar days. Because inventory dollar days treats inventory as a liability and forces a firm to concentrate on reducing the inventory that it has held for an extended time, it is one of the best ways to evaluate the impact of inventory on system performance (Goldratt & Fox, 1988). Levels of inventory dollar days may be established to buffer various control points in a shop or aircraft repair line. A dollar value that exceeds the level set for a particular point indicates excess inventory in the system (Cox & Blackstone, 1990, 1992). One factor of the inventory dollar days equation is the number of days until

the item is sold. Because an exchangeable item is not "sold" until it is issued at base level, computation of this factor is not as straightforward for exchangeables as it is for aircraft. Hence, for exchangeables, changing this factor to "number of days until shipped" (from the depot) might be more reasonable for computation purposes. Because inventory dollar days assigns the largest dollar value to the oldest inventory, it should be especially useful for motivating managers to eliminate inapplicable inventory. In addition, inventory dollar days figures for each of the four categories shown in Figure VI-4 could be combined and reported as a single figure for each directorate and/or for all aircraft or exchangeables at a depot.

Customer responsiveness involves both due date performance and quoted lead time (Goldratt & Fox, 1986). Due date performance, a measure of delivery reliability, refers to delivering on or before the time desired (Hill, 1989) and is the component addressed by the delivery criteria in Figure VI-4. An important factor in due date performance is schedule conformance, or actual deliveries versus scheduled deliveries. This factor was previously included as part of the throughput criterion. While schedule conformance assesses missed due dates, it does not distinguish between those shipments which were only a few days overdue and those orders delivered several weeks or months late. The throughput dollar days criterion makes this distinction. Because it takes into account the number

of days a shipment is late, it forces a production division to concentrate on the very late orders. This indicator would motivate depot supervisors to place a higher priority on the repair of crash-damaged aircraft. Because these aircraft require extensive repairs and are not part of the scheduled PDM/modification workload, they receive a very low priority and often remain in the depot for years.

The purpose of the flow day delivery criterion is to motivate management to reduce quoted lead times and improve on-time delivery rates. This criterion can be used to measure performance in contracting, engineering, and depot maintenance. Contract processing flow days and days to complete engineering change requests (AFLC 103s) are two examples of how this indicator can be used to assess the performance of functions that do not directly involve depot maintenance but which have a tremendous impact on weapon system support. Of course, aircraft flow days have been used for years to measure aircraft repair in AFLC. Now organizations that repair exchangeables, like WR-ALC's avionics directorate, are beginning to use shop flow days to track MISTR repair cycle time.

The MICAP hours criterion, a measure of the fill rate for critical component parts, assesses the level of customer service provided by item managers to base maintenance units. This indicator is familiar to all AFLC managers and provides a good picture of the items that are causing the most material support problems for a particular weapon system.

Reviewing the top twenty items responsible for generating MICAP hours allows management to focus its material support improvement efforts. However, because the unavailability of component parts does not always ground an aircraft, a backorder criterion has been included. Backorders represent supply requests that cannot be immediately filled and are another measure of customer service (Allen & Linteau, 1980). To focus on the most critical backorders, those backorders of lowest priority (priority categories 09 - 15) are excluded from this criterion. Age of backorders is included to put pressure on item managers to fill the oldest backorders. Age categories such as less than 90 days, 90 - 180 days, and over 180 days have typically been used in the past (Allen & Linteau, 1980). In today's competitive environment, however, categories of less than 30 days, 30 - 120 days, and over 120 days, respectively, might be more appropriate.

A competitive edge which can also improve bottom line results is innovation. In this study, innovation refers to the implementation of new technologies and new practices, such as buffer management, mistake proofing, and the use of new performance criteria. The innovation criterion proposed is similar to the DDPMS innovation criterion. The requirement to submit a qualitative narrative to directorate and depot levels outlining specific innovations and their costs and benefits should encourage the workforce to develop and implement new ideas. Because innovation can benefit

performance on each of the five competitive edges previously discussed, an innovation criterion should be included in a depot performance measurement system.

An important factor in reducing lead times is flexibility. Although flexibility can be measured along several dimensions, personnel reductions are causing workforce flexibility to become increasingly important for the AFLC. Hence, an indicator is needed to motivate supervisors and workers to place more emphasis on cross training and the development of a multi-skilled workforce. Crawford (1988), McNair et al. (1989), and Maskell (1989) recommend a metric for measuring the skill improvement of employees. A skill mix/cross training criterion is being considered for implementation by OO-ALC's landing gear division. The intent of including the word "level" in the flexibility criterion proposed in Figure VI-4 is to measure the scope and complexity of cross training so that supervisors are encouraged to conduct cross training, which ultimately translates to increased throughput and greater net profit for the directorate.

System Constraints

16. **To make depot repair more responsive to its customers, AFLC should initially concentrate on streamlining and synchronizing process flows for depot repair and all processes that support depot repair.**

Streamlining refers to eliminating unnecessary steps in a process or reducing the time required to perform individual

operations. By streamlining the repair process flow for F-16 wings, OO-ALC's technical repair division has decreased the standard labor hours for F-16 wing repair by one-half. Similarly, the use of spray sealant in place of a manual sealing process has enabled SM-ALC's aircraft directorate to substantially reduce the time required to seal F-111 fuel cells. Cycle time can also be reduced for processes not directly involved in aircraft or exchangeable repair. For example, to reduce the time required to approve and implement engineering changes, the C-141 directorate at WR-ALC has installed facsimile machines in several areas in the organization.

In a synchronized flow environment, parts and materials move smoothly and continuously from one control point (operation or process) to the next. This environment is typically characterized by short repair or manufacturing lead times and low work-in-process inventories. As a result, the organization is better able to improve product quality, reduce quoted lead times, improve due date performance, and decrease operating expenses (Umble & Srikanth, 1990). With shorter manufacturing/repair lead times, less expediting, and consequently less overtime, are necessary. Also, less investment in equipment at final operations is often undertaken. In addition, because orders do not have to be forecasted as far into the future, forecast validity is quite high. As a result, due date performance improves (Umble & Srikanth, 1990). Umble and

Srikanth (1990) provide several other illustrations of how synchronized flows can improve performance on the competitive edges of cost, quality, and delivery. They also explain how to implement synchronized manufacturing.

The five steps of the Theory of Constraints (TOC), the principles of synchronous manufacturing, drum-buffer-rope (DBR) scheduling, and buffer management are the primary means to synchronize flow of parts, products, or paperwork in a repair facility, a manufacturing firm, or a service organization. The first step in synchronizing flow is to perform the five TOC steps. Step 1 is to identify the internal resource constraint. In Step 2, the constraint can be exploited by protecting it with a buffer of material and by prioritizing its work to make the best use of its time. Step 3 involves subordinating the output of the non-constraint workstations to the constraint's pace. DBR scheduling and buffer management can be implemented in conjunction with the first, second, and third steps. Step 4, elevation of the constraint, typically consists of acquiring additional capacity at the constraint or offloading work at the constraint through subcontracting or rerouting. If step 4 eliminates the constraint, then the fifth step, identification of the new constraint, needs to be undertaken (Fogarty, Blackstone, & Hoffmann, 1991).

The principles of synchronous manufacturing are an inherent part of the aforementioned process and revolve around concepts associated with constraint and nonconstraint

resources and process and transfer batches. Basically, the capacity of constraint resources is equal to or less than the market demand placed upon them, while the capacity of nonconstraint resources exceeds market demand. Consequently, any time lost at a nonconstraint resource has a negligible effect on system throughput. On the other hand, an hour lost at a constraint equates to a lost hour of throughput for the entire system. Synchronous manufacturing also distinguishes between a transfer batch, which is the quantity moved between resources, and a process batch, the product quantity processed at one time by a resource before it changes over to the next product. In most cases, transfer batches should not equal process batches, and process batches should vary over time and at various workstations. For example, at nonconstraint resources, process batches should be kept small to maintain product flow. At constraint resources, though, process batches should be larger to ensure that the constraint is continually fed with work. Although AFLC has many policy constraints, synchronizing product flow in the backshops and on the aircraft repair lines would do much to enhance overall throughput and improve performance on the competitive edges of quality, cost, and delivery.

17. **AFLC depot maintenance organizations should focus process improvement on the internal resource constraints.**

Because the internal resource constraints control system throughput, focusing improvement efforts on these resources is most likely to have the greatest impact on the competitive edges of cost, quality, and delivery. Improvement on these edges should in turn increase throughput and net profit. SM-ALC's use of spray sealant to seal F-111 fuel cells is an example of focusing process improvement on a system (directorate) constraint, the aircraft fuels operation. In addition, a focused approach enhances implementation. Because managers and workers can see improvements to T, I, and OE in a relatively short time, they are more likely to be enthusiastic about continuing synchronization efforts. Thus, in the long run the implementation is more likely to succeed.

On the other hand, with the JIT (Just-in-Time) approach the implementation period is often difficult and lengthy. This approach attempts to eliminate inventory throughout the system, make quality improvements everywhere, and correct every problem that disrupts product flow. Because disruptions at constraint and nonconstraint resources are treated equally, corrective actions are not prioritized. Thus, time and resources are wasted solving problems that have little effect on system throughput or operating expense.

18. Top management at each ALC should concentrate on identifying policies which deter system throughput,

prevent focusing on system constraints, and inhibit achievement of command goals and depot objectives.

As Cox and Blackstone (1990) observe, in most organizations management procedures and policies constitute the biggest roadblock to achieving excellence. The ALC managers should work to change the policies over which they have control and which are inhibiting performance in their directorates. Depot policies include those policies related to organizational structures, production planning and control, cost accounting, performance measurement, and training. The product directorate reorganization in AFLC is an example of a command policy concerning organizational structure. The purpose of this policy was to restructure the depot directorates to provide better customer support. The OO-ALC aircraft directorate's organization of its backshop planning and scheduling function by process instead of by shop is an example of a policy change involving both organizational structure and production planning and control. Other planning and control policies that inhibit performance are large batch MISTR workload induction, the use of transfer and process batches of equal size at each operation, and the failure to emphasize the repair of XF (field level repair) component parts.

Cost accounting policies are not as easy to change at the local level. Due to DOD and AFLC command policies, depot managers must still use standard cost procedures for setting repair prices and for external reporting of

financial performance. However, they can begin to use T, I, and OE criteria to assess internal effectiveness and to employ alternative methods for justifying equipment investments. Funding decisions should consider the impact of the investment on system throughput and on the competitive edges. More specifically, such decisions should take into account whether money is being spent on a constraint or a nonconstraint operation and whether the competitive edges impacted represent order qualifying or order winning criteria (Hill, 1989). Ability to meet order qualifying criteria can prevent a firm from losing orders to its competitors but does not necessarily result in the firm winning additional orders from its customers. Obviously, investment to increase performance on constraint operations and on order winning criteria will result in the greatest payback in terms of system throughput and net profit.

Even though the use of standard cost procedures is still prevalent throughout the DOD and the federal government, AFLC's depot managers can implement a throughput-oriented performance measurement system for making local decisions that are consistent with command goals. In AFLC's current performance measurement system, operating expense (OE) is the predominant criterion, with cost considerations being used to make most decisions. In fact, competition is now causing AFLC managers to place an even greater emphasis on cost measurement. Instead, these managers need to make throughput (T) the dominant criterion.

While it is impossible to decrease inventory (I) and OE below zero, opportunities to improve T are unlimited. In addition, using OE as the top criterion gives the impression that an organization is a system of independent variables. Of course, an organization is actually a collection of dependent variables, and throughput reinforces this important fact (Goldratt, 1990a). Therefore, AFLC's depot managers need to deemphasize the use of capacity utilization and efficiency-based criteria like OPMD and direct labor effectiveness. The negative impact of backshop efficiency measures on system performance was discussed in Chapter V. While efficiencies are also used in the aircraft directorates, in these organizations such criteria are normally of secondary importance to due date performance.

Another policy change that can be made at depot level concerns training. Recently the depots have devoted considerable time to educating the workforce in TQM and educating management in TQM and TOC. Traditionally, though, AFLC's top managers have not emphasized training to the extent that it has been stressed in other Air Force commands. As a result, sometimes workers have not been fully qualified in their primary jobs, and cross training programs have only been given lip service. With defense budget reductions, the AFLC hiring freeze, and the DOD mandate for competition, many problems can no longer be resolved by simply throwing more money and/or more people at them. Consequently, the depots need to place a higher

priority on training, particularly on cross training in the exchangeable repair arena. Due to the greater similarity among repair tasks, cross training programs are probably easier to implement in exchangeable repair than in aircraft maintenance. The fact that competition is concentrated on exchangeables is an additional reason for focusing cross training efforts on the commodities and TI directorates.

19. **AFLC headquarters should work with the Secretary of the Air Force, DOD, and Congress to change policies related to the standard cost accounting system, the budget process, and the personnel job classification and assignment system.**

Obviously, expecting AFLC to overturn the nation's cost accounting system is unrealistic. However, AFLC can still encourage the use of new business practices and new methods for making decisions within the command. The discussion regarding the justification of investment decisions (refer to guideline 18) is one example of changing cost accounting procedures that can be accomplished at local (depot) levels. Equally detrimental to depot maintenance performance are budget policies and procedures. The lengthy DOD budget cycle and various public laws related to the budgeting process, such as the two-year moratorium on repair prices, hamper the AFLC's ability to respond to changes quickly and to compete effectively. Though revamping the budgeting process will take years, in the short term, substantial

gains could be achieved by revising laws like the one cited above.

Restrictive personnel policies constitute a major obstacle to accomplishing depot maintenance at directorate and depot levels. OPM job classification rules, along with the command's own failure to enforce certification training and emphasize cross training, restrict the development of a more flexible workforce. Managers need the authority to reclassify and/or merge job skills, as necessary. OO-ALC's proposal to combine several maintenance support skills series into two positions, technical managers and materiel managers, could certainly streamline paperwork flows and reduce processing times. However, implementation of this proposal requires approval from the OPM and the highest levels in the DOD.

The AFLC hiring and promotion freezes merely exacerbate the personnel policy restrictions. If the workforce were more flexible, the need for a hiring freeze as a means of cost reduction might not have been as great. However, as illustrated by what is happening at SM-ALC's aircraft directorate, the promotion freeze is probably even more detrimental than the hiring freeze to an organization's long-term competitive posture. In the past many AFLC organizations probably had more people than were needed to accomplish the peacetime mission. However, rather than imposing hiring and promotion freezes on all job skills at all ALCs, the command could have mandated that each ALC

reduce labor costs by a certain percentage. This action would have allowed each center commander to dictate restrictions on hiring and promotion that were appropriate for his depot.

20. **Current depot maintenance data systems should be integrated and updated so that information can be obtained from one or a few systems on performance in many areas, such as material usage, defect and reliability rates, and financial status.**

AFLC's need for real-time MISTR repair and consumable buy requirements systems that reflect current demand has already been mentioned. Obviously, reducing inventory in the system and a concept for exchangeable repair similar to the DRIVE program would help shorten repair lead times and begin to obviate the need for accurate long range forecasts. Nonetheless, the problems with the thirty different depot maintenance data systems interfacing properly and communicating with each other still cause many delays, particular in the planning and scheduling functions. Combining and redesigning these systems into a simplified network of four or five major systems for requirements, material, production, and operating expenses would certainly allow workers to accomplish their daily tasks more easily and quickly.

A prime purpose of DMMIS is to integrate the depot maintenance data systems. Although DMMIS will give the ALCs better capabilities for material requirements planning and

inventory management, it does not provide for the tracking of quality defects and reliability information, like MTBR. For most current weapon systems, special in-house programs, such as the one being piloted in WR-ALC's avionics directorate, must be developed to establish a repair history on LRUs and SRUs. The F-16 is one of the few aircraft for which a historical database of LRU and SRU field-level and depot-level repairs exists. In the near future, contractor and manufacturing history and a record of all QDRs and MDRs (materiel deficiency reports) will be incorporated in this database. For the new weapon systems now being fielded, the CIR (computer integrated repair) approach described in the C-141 case is the ultimate data system for providing quality and reliability information to technicians and managers at all levels of the manufacturing and repair process. Finally, even though a financial module has been added to DMMIS, it is still doubtful that DMMIS will be able to collect the correct data for decision making. Therefore, a requirement for special financial programs, like the one developed at WR-ALC, that provide managers the information they need for decision making will probably exist for some time.

Depot Maintenance Performance Model

The diagram in Figure VI-5 and the chart in Figure VI-6 summarize the major points presented in this chapter. The diagram depicts the relationships among the four variables of depot objectives, competitive edges, performance

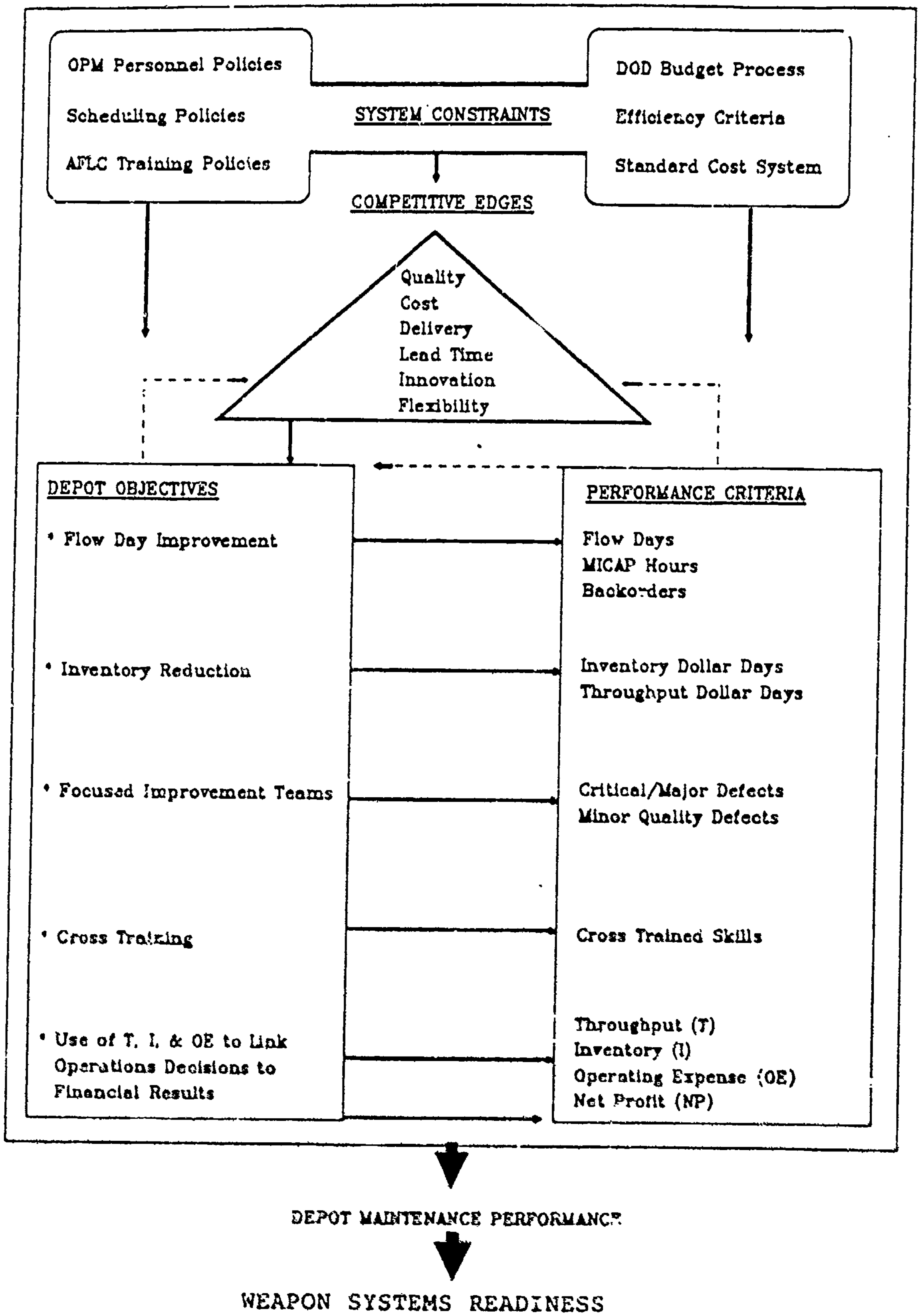


Figure VI-5. Model Proposed by This Researcher for AFLC Depot Maintenance Performance

COMPETITIVE EDGE	DEPOT OBJECTIVES (AFMC Goals)	PERFORMANCE CRITERIA
Quality	Develop focused improvement teams (People & Customer Satisfaction)	Critical/Major Defects Minor Quality Defects
Cost	Make T,I, & OE the basis for local operations decisions & for linking actions to local & global results (Business Practice) Reduce inventory to minimum levels (Business Practice)	Throughput (T) Inventory (I) Operating Expense (OE) Net Profit (NP) Inventory Dollar Days
Delivery	Deliver aircraft and job routed orders to the customer on or ahead of schedule at least 95% of the time (Customer Satisfaction)	Throughput Dollar Days
Lead Time	Improve aircraft and shop flow days to competitive levels (Customer Satisfaction)	Flow Days MICAP Hours Backorders
Innovation	Implement new practices and update technology and equipment to ensure future throughput and sustain weapon system readiness (All AFMC Goals)	Innovation Narrative
Flexibility	Make cross training a top priority (People & Customer Satisfaction)	Number/Level of Tasks to Which Cross Trained

Figure VI-6. Relationship Among the Elements in the AFLC Depot Maintenance Performance Model

criteria, and system constraints in achieving weapon systems readiness. The reasons for including the elements shown under each of the first three variables were outlined in conjunction with guidelines 3, 4, and 15, respectively. The six constraints shown in the "yoke" at the top of Figure VI-5 relate to policies and refer to seven of the eight core constraints shown in the ECE diagram for AFLC depot maintenance (Figure V-44). As discussed in Chapter V, these eight core constraints may be linked to two root problems - traditional cost accounting philosophy and personnel policies. Because the eighth constraint, data from the G019 and D041 systems, stems more from archaic information systems than from cost accounting or personnel policies, it is not included in the diagram in Figure VI-5.

The solid and dashed arrows in Figure VI-5 represent driving forces and supportive forces, respectively. A driving force is one which has a great influence or impact on a model variable, while a supportive force is one which sustains or upholds a variable. The competitive edges shown in the model are the six competitive edges examined in this dissertation. They are listed in the order in which they were most frequently ranked by the AFLC managers surveyed in this study. An analysis of the data revealed that these managers considered quality, cost, and delivery to be the most important edges. The competitive edges represent the areas in which the AFLC must succeed to be competitive and remain in business. Thus, they should determine, to a large

extent, the strategy, as reflected by the command goals and depot objectives, that the AFLC chooses to pursue.

In turn, the goals and objectives will determine, on a macro level, the areas of performance, and, in a micro sense, the performance criteria that are emphasized. The seven depot objectives in Figure VI-5 are capsule summaries of the seven objectives listed in Figure VI-1 and discussed in conjunction with guideline 3. Technically, the first and the seventh objectives on focused improvement teams and cross training are not objectives but are actually means to achieving objectives related to quality and flexibility. However, because in many cases a minimum level of process improvement and workforce flexibility has not yet been attained by AFLC depot maintenance organizations, focused improvement teams and cross training were included as objectives in the model. Of course, the goals and objectives need to reflect the importance of the competitive edges, and the performance criteria should support the goals and objectives and reinforce performance on the competitive edges. With that rationale in mind, the performance criteria in Figure VI-5 were selected for inclusion in the model because they focus on system constraints, measure performance on the competitive edges, and support the AFLC goals and depot objectives. These criteria are outlined in Figure VI-4 and were discussed in detail under guideline 15.

While the model in Figure VI-5 uses solid arrows to designate the performance criteria that correspond to each depot objective, it does not illustrate how the competitive edges relate to the proposed depot objectives and performance criteria. The chart in Figure VI-6 maps the relationships among the individual elements of the model variables of competitive edges, depot objectives, and performance criteria. The competitive edges are listed to the left of the depot objectives to which they most closely correspond. The relationship illustrated between the competitive edges and the depot objectives in Figure VI-6 replicates that shown in Figure VI-1. The discussion for Figure VI-1 explained how the fifth objective for flow days impacts both lead time and delivery and how the inventory reduction objective affects not only cost but also quality, lead time, and delivery. Figure VI-6 also contains a qualitative criterion for innovation that is similar to the DDPMS innovation indicator. Innovation is primarily a long-term goal that enables a firm to compete more effectively on the other five competitive edges and to retain customers in the future. Despite the recent budget reductions, the AFLC is expected to continue to provide the support necessary to ensure the highest levels of weapon systems readiness. Obviously, innovation is critical if the command is to sustain readiness on a smaller budget.

Figure VI-6 also depicts the AFMC goals that correspond to each depot objective. These goals are shown in

parentheses following each objective. The AFMC goals, rather than the AFLC goals, were included in Figure VI-6 because these goals will officially become the command goals for AFLC operations on July 1, 1992. According to Goldratt (1990b), a global goal and performance criteria that enable managers to judge the impact of local decisions on this goal form the foundation of any organization and are the first things that must be defined by the organization. The performance criteria and the depot objectives listed in Figure VI-6 and in the depot maintenance performance model represent an attempt to provide some focus for remedying internal resource constraints and the standard cost system and training policy constraints present in AFLC depot maintenance.

To implement the proposed performance criteria, AFLC managers should adhere to recommendations from leading performance measurement researchers and principles advocated by such action programs as TQM, JIT, and TOC. Of course, several principles or actions may be undertaken to support a single goal or objective or the implementation of a single performance criterion. Recommendations from performance measurement researchers that are applicable to AFLC performance measurement are the use of trends for measuring quality and inventory (Crawford, 1988), the use of a few simple measures (Dixon et al., 1990; Maskell, 1989), the elimination of the concept of direct labor (Vollmann, 1988), and the elimination of cost allocation (Goldratt, 1990b).

All the ALCs examined in this study used trends for measuring aircraft defects, WIP investment, production output, and schedule conformance. Nearly every directorate tracked operating expenses and funds expenditures on a monthly basis for the fiscal year to date. A trend toward fewer criteria, especially at the headquarters level, also exists. The ten DDPMS criteria and the six criteria proposed by AFLC headquarters represent a dramatic change from the AFLC productivity measurement matrix and the 36 Meaningful Measures of Merit (McClaugherty, 1984) that were in vogue in the command in the mid-1980s. An even more drastic change is the elimination of the direct and indirect labor categories from the proposed AFLC command-level criteria. With the recent workforce reductions and proposals to merge job skills, the distinction between direct and indirect labor no longer seems necessary. Nonetheless, for the command to approve the elimination of this distinction in its performance measurement system would have been unthinkable just a few years ago.

A number of performance measurement research recommendations are quite compatible with AFLC's TQM environment. For example, teamwork is one of the basic tenets of AFLC's TQM program. Several researchers, such as Crawford (1988), McNair et al. (1989), and Stalk and Hout (1990), advocate the use of team-based performance measures for the measurement of schedule conformance and delivery. The throughput dollar days and inventory dollar days

measures proposed by Goldratt and Fox (1988) are also team-based. Although no examples of team-based measures were found in this study, the engineering branch chief for OO-ALC's landing gear division recommended that the division's product teams be assessed on their performance as a team in supporting a particular product line or weapon system.

The first depot objective, development of focused improvement teams, embraces principles embodied in JIT, TQM, and TOC. A common element of the JIT philosophy is small group improvement activities for improving quality and productivity (Crawford et al., 1988). Team building and continuous improvement are well known TQM principles. Process improvement activities may incorporate a number of the TQM practices advocated in Deming's 14 points for continuous improvement and Juran's five points concerning the vital few projects. Quality control techniques like SPC, Pareto analysis, fishbone diagrams, and mistake proofing may also be used (Fogarty et al., 1991).

However, because of tremendous differences in the marginal value of time at constraint and nonconstraint resources, the return on improvements made at nonconstraint resources primarily impacts OE and is often insignificant in terms of its impact on system throughput. Thus, for AFLC the primary contribution of the TOC process improvement approach is to help prioritize improvements and focus them on constraint operations so that the greatest impact on the global goals of making money and maintaining weapon systems

readiness is achieved (Umble & Srikanth, 1990). Additionally, improvement activities should focus on order winning criteria, as defined by the customer (Hill, 1989). In this period of reduced funding for equipment investment and spares inventories, being able to maximize and prioritize improvement opportunities is crucial.

The second concept inherent in the first depot objective in Figure VI-6 is the development of people, which is a central theme in the TQM philosophy and a cornerstone of the AFLC and AFMC goals. Although TQM Process Action Teams (PATs) exist at every depot, in many cases these teams only include some of the individuals assigned to a first-line supervisor. To ensure total employee involvement and commitment, this researcher envisions a focused improvement team to be comprised of all the workers involved with the repair of a particular product. Because these workers would be assigned to more than one branch, the first-line supervisors from all concerned branches would be members of this team. The team might also include planners, schedulers, engineers, and equipment specialists, as required. The team would concentrate on the development of process improvements, particularly at constraint operations, and the correction of critical/major and minor quality defects. The first-line supervisors would also emphasize cross training as a means for improving workforce flexibility (the seventh depot objective) and enhancing

workers' understanding of the effects of local improvements on system performance.

These teams would also include a facilitator from the directorate's TQM center. The facilitator would be trained in TQM principles and in such JIT practices as preventive maintenance, the development of multi-skilled workers, reduction of lot sizes, setup time reduction, and supplier involvement. The facilitator would also be educated in the principles of synchronous manufacturing, buffer management, and constraint identification (five steps of TOC). Ideally, all facilitators would be volunteers with hands-on depot maintenance experience or a sufficient understanding of depot maintenance operations. Trained TQM facilitators are already guiding the activities of the PATs formed in the Commodities Directorate at SM-ALC. These facilitators have reported several success stories regarding the electrical generator repair process.

The purpose of the second depot objective is to revise the basis on which local operating decisions are made. The allocation of overhead on the basis of direct labor cost distorts product costs and leads to poor decision making (Cox & Blackstone, 1992). Indeed, the standard cost system as a whole fails to provide a systemwide perspective on the impact of specific actions (Umble & Srikanth, 1990). Therefore, a mechanism is needed for linking day-to-day operations decision making to financial results. The manner in which the T, I, and OE criteria can be linked to the

measures of net profit and ROI has already been illustrated. It has also been shown how T, I, and OE, in conjunction with the constraint identification process, can be used to justify investment decisions.

The second depot objective proposed also implies greatly deemphasizing traditional efficiency and utilization measures. The use of these criteria assumes that depot maintenance performance is maximized when all entities within the system are operating at maximum efficiency and utilization. Of course, because constraint operations should be fully utilized at all times, the use of efficiency criteria to measure the performance of constraints is perfectly logical. However, the incongruencies in the present AFLC performance measurement system often result in behavior and actions that fail to support the global goals and command mission. The detrimental effect of efficiency-based performance criteria on aircraft due date performance was apparent at every depot visited in this study. All other objectives must be scrutinized against the second objective. Failure to meet this objective will greatly hinder achievement of the other six proposed objectives. In short, the development of viable indicators to link AFLC operations decision making to customer expectations and financial results is critical to AFLC's business success.

As previously noted, accomplishment of the third depot objective related to inventory reduction can not only reduce lead times and improve due date performance but also result

in better quality. Of course, inventory reduction is a type of waste elimination, a concept which lies at the heart of the JIT philosophy. The traditional MRP approach to production and inventory management that is utilized in AFLC involves the placement of large WIP inventories throughout the system to buffer the impact of dependent resources and random fluctuations. Dependent resources refers to the fact that repair operations are linked, and random, or statistical, fluctuations are simply due to random problems (Cox & Finch, 1989; Fogarty et al., 1991). The kanban pull method of production inherent in JIT manufacturing spreads small amounts of WIP throughout the production system and attempts to eliminate random fluctuations. The JIT approach to process improvement is to wait until problems occur and then correct them. Unfortunately, disruptions severe enough to cause work stoppage at one operation often jeopardize product flow and throughput for the entire system.

On the other hand, the DBR scheduling method employed in synchronous manufacturing and the TOC philosophy is a proactive approach that attempts to prevent problems and protect system throughput by placing buffers at strategic locations in the system (Cox & Finch, 1989; Umble & Srikanth, 1990). In addition, the minimum amount of inventory required to make the kanban method work in the make-to-order job shop environment that characterizes most AFLC backshop operations would be immense (Umble & Srikanth, 1990). Therefore, the best way to reduce inventories in

AFLC depot maintenance operations is through buffer management and placement of inventory at strategic control points in the system. This approach was briefly described in conjunction with guideline 15 and is explained in detail by Cox and Finch (1989).

The purpose of this research was to prescribe a model for AFLC depot maintenance performance which adhered to the characteristics listed in Chapter I. The results of the rankings of the six competitive edges by AFLC supervisors provided a common basis for comparison with performance measurement research conducted in the private sector (refer to Lockamy, 1991) as well as a starting point for the development of this model. To ensure completeness on important issues and fertility of consequences, the core constraints identified in the AFLC ECE diagram (see Figure V-44) and the need for many AFLC organizations to identify and eliminate internal resource constraints were the primary factors taken into account in developing the depot objectives. Secondary considerations were the three highest ranking competitive edges and the AFMC goals. Simplicity in the model was achieved by limiting the number of depot objectives and making criteria related to T, I, and OE the cornerstone of the performance measurement system. Finally, to provide robustness, the model included performance criteria for measuring both aircraft and exchangeable repair and performance on all six competitive edges. Robustness

was also enhanced by excluding specific targets from the depot objectives.

The purpose of the prescriptive model is to offer an integrated approach to AFLC performance measurement. The model expands on the strategy, actions, and measures connection proposed by Dixon et al. (1990) to include specific elements related to strategy and measures as well as additional variables for system constraints and competitive edges. The constraints impact all other model variables. The competitive edges represent the expectations of the AFLC's customers. The criteria related to quality and delivery measure operations (depot maintenance or production) performance on the competitive edges of quality and delivery and represent a way to link operations decisions to customer expectations. The cost criteria link maintenance decisions to the directorate's and the depot's financial results and to customer expectations regarding price and value.

Of course, implementation of depot objectives and performance criteria requires action programs. The TOC approach for identification of system constraints provides a method for focusing the continuous improvement efforts of TQM and the waste elimination and inventory reduction activities of JIT. Essentially, JIT improves lead times and due date performance, TQM improves people, and TOC provides focus for the entire improvement process. To compete with other depots and with private industry, the AFLC must become

the low-cost repair agency capable of offering high quality repairs and superior customer service, in terms of due date performance and quoted lead time. Hopefully, this model and the associated guidelines and ECE diagrams can provide insights for assisting the AFLC's depots to become more competitive.

Dissertation Summary, Implications, and Limitations

Dissertation Summary

The research presented in this dissertation was an exploratory study of the performance measurement systems used by AFLC's aircraft repair depots and the system constraints present in these depots. This dissertation explored the issues impacting the performance of six depot maintenance organizations and the performance criteria used by these organizations to assess performance. By means of survey instruments and on-site interviews, managers at four levels in these organizations were asked to identify and rank the competitive edges on which their depots compete. These supervisors were also asked to rate the congruency between their depot and directorate objectives and their directorate's performance criteria. In addition, managers at the directorate and division levels evaluated the congruency of AFLC goals and depot objectives. The outcome of this research was the development of a depot maintenance performance model and a set of guidelines concerning AFLC goals and depot objectives, competitive edges, performance criteria, and system constraints.

A case study methodology was selected for this study because the development of guidelines and a system performance model required an in-depth understanding of the AFLC depot maintenance environment at the directorate, division, branch, and first-line supervision levels. This type of methodology also allows for the use of multiple sources of evidence in the data collection and analysis processes. To collect fundamental information on each organization's structure and workload, pre-visit questionnaires were mailed to each directorate. To ensure that similar data was collected from each depot maintenance organization, on-site interview instruments were employed. Interviews were tape recorded and the tapes were transcribed by this researcher to assure completeness and accuracy. Survey instruments were used to identify competitive edges, rate the congruency of AFLC goals and depot objectives, and assess the congruency of depot objectives and performance criteria. The survey instruments were administered to directorate, division, branch, and first-line supervisors during the on-site visits.

This dissertation answered the four research questions presented in Chapter I and outlined below:

(1) Is there congruence between the goals of the Air Force Logistics Command (AFLC) and the depot-level and directorate-level objectives of its aircraft repair depots?

(2) Do managers at the directorate, division, branch, and first-line supervision levels agree on the ranking of

the criticality of the competitive edges for accomplishing depot maintenance?

(3) Do performance criteria used at the directorate, division, and branch levels support the accomplishment of AFLC goals and directorate and depot objectives? If not, what are some criteria that would better support these organizations' objectives?

(4) What types of constraints exist in these depots, and how do these constraints impact depot performance?

These questions were addressed in detail for each depot maintenance organization in the six case studies presented in Chapter IV. An analysis of each case with respect to the research questions and a cross-case analysis highlighting the similarities and differences between the participants was presented in Chapter V. The results in Chapter V were used as a basis for developing the set of guidelines and the depot maintenance performance model presented in Chapter VI.

The major findings of the four research questions may be summarized as follows. In regard to the first question, this researcher and the depot managers surveyed believe that congruence does exist between the AFLC goals and the depot objectives. For the second research question, the survey results indicated that depot managers believe quality, cost, and delivery to be the most critical competitive edges, in that order. Concerning the third question, this researcher determined that the current AFLC performance criteria do not adequately support the accomplishment of AFLC goals and

depot objectives. Hence, new criteria were proposed as part of the depot maintenance performance model. This model also included the managerial constraints related to personnel policies and the traditional cost accounting philosophy that were found in the organizations examined in this study and that are the subject of the fourth research question.

Implications for Practitioners

Depot performance measures was included among the thesis topics recently submitted by AFLC to the commander of the Air Force Institute of Technology (Searock, October 30, 1991). Thus, this dissertation directly addresses a research need identified by AFLC commanders and key managers. The case studies, and the cross-case analysis in particular, identified the similarities and differences that exist in depot maintenance objectives, competitive edges, performance criteria, and system constraints. Such identification should make depot practitioners more aware of the constraints that exist in their organizations and of the objectives and performance criteria that are being used by various ALCs to guide and measure organizational performance. The increased awareness should improve communication among the depots in regard to performance measurement issues and the elimination of system constraints.

Concerning AFLC goals and depot objectives, the cases provided detailed examples of objectives established by various aircraft and support directorates and divisions.

Many case interviews revealed that dramatic changes were being initiated in strategies, goals, measures, and actions based on the introduction of TOC into some portions of the organization. For instance, inconsistent efficiency-based measures were being questioned and, in some cases, their importance downgraded. By examining these examples, depot practitioners should be able to obtain some ideas on the goals and objectives that are appropriate for their organizations. They should also be able to see how their current objectives are related to the proposed AFMC goals. The goals and objectives of SM-ALC's aircraft directorate provide an especially detailed example of organizational goals and objectives which, with minor revisions, would be applicable to many of the organizations in this study. The study also revealed that aircraft division chiefs rated the congruency of AFLC goals and depot objectives much lower than did aircraft directors and support directors and division chiefs. This result could indicate that aircraft division chiefs are not totally cognizant of depot objectives or that current depot objectives do not reflect what aircraft division chiefs perceive to be their divisions' objectives.

Although it is evident from Table V-3 that not much difference exists in the ranking of competitive edges across the six depot maintenance organizations, the table does indicate the importance that supervisors in each of these organizations place on these elements. By examining the

detailed rankings provided in the applicable case writeups, directorate and division chiefs from the three ALCs in this study can gain a better understanding of how supervisors at four different levels of their organization view the six competitive edges. With a better understanding of the differences in competitive edge rankings that exist across organizational levels, directors should more readily perceive a need to communicate depot and directorate objectives to the lowest levels of their organization.

Communication of organizational goals and objectives to first-line levels should help supervisors at these levels better understand the relationship between performance criteria and depot objectives. Reviewing Tables V-4 and V-5 should allow directors to easily see how supervisors at different levels rate the congruency of performance criteria and depot objectives and to determine where the greatest differences in these congruency ratings exist in their organizations. More importantly, Tables V-6 and V-7, as well as the individual case write-ups, might assist depot managers in selecting appropriate management indicators at division and directorate levels. For example, many of the units at OO-ALC and SM-ALC do not currently measure contracting or engineering performance. By looking at criteria used by WR-ALC directorates, OO-ALC and SM-ALC managers might obtain ideas on contracting and engineering criteria suitable for their ALCs.

An examination of the ECE diagram for their organization should reveal to managers how incongruent and inconsistent performance criteria are responsible for some of the problems in depot maintenance system performance. Additionally, these diagrams play an important role in identifying organizational policy constraints and can be used to show depot managers how policies and actions impact seemingly unrelated areas. By reviewing the ECE summary diagram in Figure V-44 and the ECE diagrams for the individual cases, depot supervisors should gain a better understanding of the effect-cause-effect relationship that exists among various system constraints. In addition, the system constraint narratives from depot maintenance organizations at other ALCs should give managers insights on how to solve problems at their depot. For instance, the TI director at WR-ALC is interested in reducing the time that job orders spend in the planning and scheduling cycle. He recently learned that OO-ALC's organization of backshop planners and schedulers by process, rather than by shops, has helped OO-ALC reduce planning and scheduling flow time. Although this revelation may not offer the entire solution to TI's problem, it certainly has made the TI director think about an aspect of planning and scheduling which he had never before considered.

Finally, even though this study focuses on depot-level maintenance organizations, some of the findings concerning system constraints and performance criteria should have

application for base-level maintenance organizations. While many depot performance criteria are not applicable to on-equipment base maintenance squadrons, a few of these criteria could be adapted by the off-equipment organizations. For example, flow days and customer reported defects could be used to assess the performance of phase maintenance. Indicators related to critical items and "G" condition assets might be useful for an intermediate jet engine or avionics repair shop. For base-level units, the only blocks in the ECE diagram in Figure V-44 that apply directly to base-level maintenance are those involving process definition and resource constraint management. The real value of the ECE diagrams, however, lies in the insights that they can offer base-level maintenance personnel on depot operations and the depot maintenance system. In general, very little crossfeed exists between depot and base maintenance organizations. Hence, the ECE diagrams are one method to enhance crossfeed between Air Force maintenance levels as well as between various depot-level maintenance organizations.

Implications for Researchers

Because this dissertation is concerned with the congruency between strategic objectives and performance criteria in a nonprofit organization, it provides empirical research in two areas where research is lacking. Linkages between functional and business level performance measures in manufacturing firms were addressed in detail in only nine

of the more than 200 performance measurement publications reviewed by this researcher. Furthermore, only three studies in the military literature addressed the need for performance criteria at all levels to support command goals and organizational objectives. Therefore, this dissertation can assist researchers in understanding the relationships between a nonprofit organization's strategic goals and objectives and the performance measurement systems used at the strategic and operational (i.e., directorate and division) levels. The guidelines concerning performance criteria can be used by researchers to generate testable hypotheses for larger scale studies in DOD depot maintenance and in other nonprofit organizations. In addition, the performance criteria proposed in the model in Figure VI-5 could be tested by researchers in DOD depot maintenance organizations to assess their practicality and their congruency with depot and command goals. Pilot studies in depot maintenance organizations involving the implementation of new performance criteria are one of the best ways to determine whether the data collection necessary for these criteria is feasible and whether the criteria are useful for decision making at all levels.

The goals and competitive edges proposed in the depot maintenance performance model, along with the associated guidelines, could also be tested by researchers in various DOD depot maintenance organizations. The results of this study imply the need for future performance measurement

research in two areas related to the first two research questions. First, this study implies that goals are important for providing direction for an organization and for determining the elements on which that organization competes. Although most research participants rated the congruency between AFLC goals and depot objectives as great or significant, a number of them observed that the goals did not accurately express the command's true purpose. Thus, additional research is required to determine how meaningful goals can be developed for a nonprofit organization and to assess the relationship between goals and competitive edges.

Second, this study showed that, for the depot maintenance organizations examined, the rankings of the competitive edges were dependent on the basis on which these edges were ranked. On the basis of depot or directorate objectives, delivery was ranked as the second most critical competitive edge by two-thirds of the organizations. However, on the basis of depot or directorate performance criteria, two-thirds of the organizations ranked cost as the second most important edge. These findings are further proof of the lack of congruency between AFLC depot objectives and performance criteria. Indeed, they illustrate the need for additional research on the appropriateness of the six competitive edges selected in this study and the value of AFLC management indicators for performance assessment and decision making.

The case discussions of system constraints and the associated ECE diagrams can aid researchers in understanding how identifying and managing a system's constraints can be used to focus the improvement process. These diagrams represent one of the first research efforts aimed at applying the Theory of Constraints philosophy to nonprofit organizations and could possibly be used as a basis for assessing constraints in other nonprofit firms. The guidelines regarding system constraints follow quite logically from the ECE diagrams and contain several specific recommendations. To determine their applicability and impact on system performance, these recommendations should be tested in various aircraft and support depot maintenance organizations. Though the authority for effecting changes in the DOD budget cycle and OPM classification policies is far above AFLC depot levels, the feasibility of these suggestions needs to be researched and considered. Despite the difficulty of testing all the guidelines, this exploratory study can give researchers a starting point for refining performance measurement theory as it applies to nonprofit firms not involved in traditional manufacturing activities.

Limitations of the Study

Because this dissertation employs a case study research methodology, it is difficult to generalize the research findings. Building theory from cases may result in a narrow theory that describes a very specific phenomenon. Thus, the

theorist is unable to generalize the theory to other situations. The theory derived from the empirical evidence of case studies may also be overly complex and lack the simplicity of an overall perspective.

Additional limitations related to the scope of this study and the time available for conducting it are as follows:

(1) The scope of this research was limited to theory development. Theory testing requires further research.

(2) For each case, the research was limited to a few selected divisions and branches in two or three directorates at an ALC. Although a few engineering branch chiefs were interviewed, the majority of the divisions and branches examined were directly involved in the maintenance, repair, and production of aircraft and aircraft component parts. While functions like item management and contracting are important for supporting aircraft depot maintenance, these functional areas were not included in the data collection process. Also, other facilities responsible for depot repair of these aircraft, such as other ALCs, overseas depots, and private contractors, were not included in the case studies.

(3) Case information and analysis conclusions are based on data collected at a particular point in time. Due to the many organizational changes occurring in the Air Force and in AFLC, certain information, particularly details in the individual cases, may no longer be valid.

To address this data accuracy limitation, the researcher made follow-up telephone calls to AFLC headquarters and the three ALCs in this stud, within three to four months after the data collection per to ensure that this dissertation contained the most current information. In addition, the pre-visit questionnaires, on-site interview tapes, and on-site interview notes allowed for data triangulation in the case studies. The survey instruments for branch chiefs and first-line supervisors were also used as a means of cross-checking information obtained in the interviews. Whenever conflicting information was discovered during data analysis, clarification was sought from the appropriate directorate or division. Completed cases with a detailed description of AFLC goals and depot objectives, competitive edges, performance criteria, and system constraints were returned to participating depot maintenance organizations for review. Final approval for release was obtained for all cases included in the dissertation.

To raise the generality of the theory, the sample selected for the study represented a cross-section of AFLC's depots and of the types of aircraft repaired by the command. The maturity of the weapon systems and the kind of depot repair performed on these aircraft also varied. For example, the study examined depot maintenance for the oldest cargo plane (the C-130), the newest fighter jet (the F-16), and the oldest fighter aircraft (the F-4) in the Air Force's

active fleet. Depot maintenance for three of the aircraft - C-130s, F-111s, and F-4s - primarily consisted of PDM, while that for the A-10s and the F-16s focused on modification programs. On the other hand, C-141 depot maintenance involved both PDM and major modifications.

Each of the three ALCs visited had aspects of its operation and organizational structure that were unique. However, because all these depots are part of the same command and the same military service, a great deal of commonality existed concerning policies, organizational goals and objectives, and basic operating procedures. Strong similarities in regard to competitive edges and system constraints also existed across the six depot maintenance organizations. Thus, the theory developed in this dissertation does not appear to be limited by ALC or by aircraft type. In addition, performance measurement literature and Theory of Constraints principles were used to substantiate the guidelines and justify the elements included in the depot maintenance performance model. To ensure a more general, but nonetheless parsimonious model, an attempt was made to limit the elements included for each of the four variables to those that exhibited the greatest degree of commonality across cases and/or were the most crucial for overall depot maintenance performance.

Conclusions

The empirical evidence from this study tends to validate the strategy, actions, and measures connection

proposed by Dixon et al. (1990) as well as Goldratt's (1990b) assertion on the importance of goals and performance criteria as prerequisites for constraint identification and elimination. Hence, several conclusions concerning AFLC depot maintenance performance and the four research questions in this dissertation may be drawn. First, realistic command goals and specific depot objectives that provide organizational direction and achievable targets are essential to AFLC's survivability. Without meaningful command goals and depot objectives, directorate and division managers may take actions which conflict with global goals and hamper the competitive capability of their depot. Second, the similarities between the competitive edges identified by world class manufacturers (Lockamy, 1991) and by the participants in this study offer justification for the applicability of findings from performance measurement research conducted in manufacturing firms to nonprofit organizations like AFLC depot maintenance and vice versa. With competition and budget reductions becoming routine, AFLC's operations will continue to be more business-oriented than in the past. Consequently, the need for performance criteria that support command and depot goals and objectives and that assist managers at all levels in making decisions that do not conflict with these goals and objectives is particularly acute.

Therefore, the third conclusion is that performance criteria for nonprofit organizations must be tied directly

to organizational goals and objectives and should focus on the organization's competitive edges. In addition, these performance criteria must be consistent across functional areas and organizational levels, enabling managers at all levels to make decisions that support the global goals. Lack of consistency between aircraft and support directorates (e.g., aircraft flow days versus shop efficiencies) is a major weakness in AFLC's performance measurement system and a significant impediment to depot maintenance performance. Hence, for AFLC to be truly competitive, performance criteria that are more congruent with depot objectives must be implemented.

Thus, the fourth conclusion related to system constraints logically follows. In the immediate future, AFLC can best improve its competitive posture by focusing on the identification and elimination of physical and logistical constraints, including the implementation of new performance criteria. Additionally, by identifying specific constraining policies, depot managers can focus their attention on eliminating or changing these policies first. An extremely short timetable for meeting mandates imposed by competition has been levied upon AFLC's depot managers. These mandates cannot be met without a substantial improvement in depot maintenance performance. Employing Theory of Constraints principles and tools should assist depot managers in focusing their improvement efforts. For the command to achieve performance improvement in the long

term, however, a sustained emphasis on training and the revision of managerial policies at the highest levels of DOD will be necessary.

Future Research

One of the most beneficial methods for focusing continuous improvement is the effect-cause-effect (ECE) diagram. Essentially, the ECE diagrams employed in this study answer the question concerning what to change. These kind of ECE diagrams, which are known as current reality trees, can help managers identify core problems in their organizations and expose the causes of these problems. As demonstrated by this research, current reality trees can also aid in the identification of organizational policy constraints. For researchers and practitioners, the current reality tree is an extremely powerful tool for problem identification and for understanding the interactions between system components and their effect on system performance. For case study researchers, ECE diagrams can be especially useful for performing cross-case analysis and detecting similarities and differences across cases in all types of profit and nonprofit organizations.

Unfortunately, current reality trees cannot be used to find solutions to core problems or to implement these solutions. As this dissertation did not offer problem solutions or address solution implementation for AFLC depot maintenance, these areas denote opportunities for further research. The problems identified by the ECE diagrams in

this study represent major obstacles to depot maintenance performance that must be eliminated for AFLC to be truly competitive. To identify and implement solutions to these problems, additional types of ECE diagrams, such as future reality trees and prerequisite trees, have been developed. Like the current reality tree, these tools are very useful. However, proficiency in building ECE diagrams requires special training and much practice. Because ECE diagram construction is not yet widely taught in secondary schools or universities, for the present time the use of these diagrams in case study research will probably be somewhat limited. Nonetheless, ECE diagrams could be useful for conducting case study research in other types of nonprofit firms, such as hospitals and universities. Although this dissertation focused on performance measurement in a military nonprofit organization, the findings highlighted in the guidelines and the depot maintenance performance model might be applicable to other types of nonprofit organizations and could be used as a starting point for research in these firms.

In regard to depot maintenance, this dissertation did not include an assessment of the appropriateness of the criteria proposed in the depot maintenance performance model or of the objectives proposed for the ALCs. Though such assessments would be highly useful for implementing changes in AFLC's performance measurement system, they were beyond the scope of this study. Future research is needed to

determine what performance criteria are suitable for the competitive edges identified and the types of directorates (i.e., aircraft and support) examined in this study. Further research is also required to verify the relevancy of the elements included in the depot maintenance performance model developed in this dissertation and to determine if additional elements or variables are needed in this model. For instance, to improve the generalizability of the competitive edge rankings, pre-visit questionnaires and surveys need to be given to a much larger sample of AFLC managers at directorate, division, branch, and first-line supervision levels. Expansion of the sample to include managers from the depots of all military services would also enhance theory generalizability.

However, generalizability could best be enhanced by expanding the scope of the study beyond the depot maintenance arena to encompass all organizations in the entire Air Force logistics spectrum illustrated in Figure IV-1. Included in this spectrum are maintenance, supply, and distribution (transportation) organizations at the depots and operational bases as well as strictly depot-level functions like item management and product engineering and technical support. One of the weakest links in the depot-to-base customer delivery chain concerns distribution. Current pipeline times are far too long and not at all competitive with private industry. Although some research on the pipeline problem has been undertaken (see Bond &

Ruth, 1989), additional research focusing on pipeline performance measurement is needed.

Besides examining the logistics cycle, the relationship of an AFLC performance measurement system to the many other management information systems already in existence should be considered. Additional research to determine how best to tie a performance measurement system into existing MISs to avoid duplication of effort and information and enhance decision-making capability would be beneficial, especially in light of the continuing reductions in funding and personnel. Research should be conducted to determine how the performance measurement system could complement or be incorporated as part of present systems like DMMIS, WSMIS (Weapon System Management Information System), and REMIS (Reliability Engineering Management Information System). Parallel efforts related to TQM, bar coding (see Pate, 1991), and financial status reporting should also be taken into account when implementing a new performance measurement system in AFLC. Therefore, to ensure that this system is truly viable will require the consideration of performance measurement in the context of DOD depot maintenance, the Air Force logistics spectrum, and related AFLC management information systems.

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APPENDIX

AIR FORCE ACRONYMS

AFLC - Air Force Logistics Command

AFLC 103 - Engineering Change Request

AFMC - Air Force Materiel Command

AFSC - Air Force Systems Command

ALC - Air Logistics Center

AMREP - Aircraft/Missile Maintenance Production Compression Report

COD - Cost of Operations Division

DDMC - Defense Depot Maintenance Council

DDPMS - Defense Depot Performance Measurement System

DLA - Defense Logistics Agency

DMIF - Depot Maintenance Industrial Fund

DMMIS - Depot Maintenance Management Information System

DOD - Department of Defense

D041 - Recoverable Consumption Item Requirements System

DPAH - Direct Product Actual Hour

DPEH - Direct Product Earned Hour

DPEM - Depot Purchased Equipment Maintenance

DPSH - Direct Product Standard Hour

DRIVE - Distribution and Repair in Variable Environments

FCF - Functional Check Flight

FMC - Full Mission Capable

FY - Fiscal Year

G019 - MISTR Requirements System

IM - Item Manager

JON - Job Order Number

LA - Aircraft Directorate

LI - Commodities Directorate

LY - Avionics Directorate

LRU - Line Replaceable Unit

MAC - Military Airlift Command

MAJCOM - Major Command

MDR - Materiel Deficiency Report

MIC - Maintenance Inventory Center

MICAP - Mission Capability

MISTR - Management of Items Subject to Repair

MDS - Mission, Design, and Series

MTBF - Mean Time Between Failure

MTBR - Mean Time Between Removal

NARF - Naval Air Rework Facility

NDI - Non-destructive Inspection

NMCB - Not Mission Capable for Maintenance and Supply

NMCM - Not Mission Capable for Maintenance

NMCS - Not Mission Capable for Supply

NRTS - Not Reparable This Station

NSN - National Stock Number

OC-ALC - Oklahoma City ALC

O & M - Operations and Maintenance

OO-ALC - Ogden ALC

OPM - Office of Personnel Management

OPMD - Output per Paid Manday

OPR - Office Of Primary Responsibility

OR - Operational Ready

OSD - Office of the Secretary of Defense

PAT - Process Action Team

PDM - Programmed Depot Maintenance

PPBS - Planning, Programming, and Budgeting System

PR - Purchase Request

QA - Quality Assurance

QC - Quality Control

QDR - Quality Deficiency Report

RCC - Resource Control Center

REMIS - Reliability Engineering Management Information System

RFP - Request for Proposal

RGC - Repair Group Category

RIF - Reduction in Force

RSD - Reparable Support Division

SA-ALC - San Antonio ALC

SM-ALC - Sacramento ALC

SPM - System Program Manager

SRU - Shop Replaceable Unit

SSD - System Support Division

TCTO - Time Compliance Technical Order

TI - Technology and Industrial Support Directorate

TO - Technical Order

TQM - Total Quality Management

TRC - Technology Repair Center

WR-ALC - Warner Robins ALC

WSMIS - Weapon System Management Information System

DIRECTORATE LEVEL
PRE-VISIT QUESTIONNAIRE
PERFORMANCE MEASUREMENT STUDY

GENERAL INSTRUCTIONS:

This questionnaire may be completed with either a pencil or a pen. For questions that use "other" or "please explain", feel free to attach a separate sheet of paper to provide a complete answer.

PART A: **General Information**

1. Please list, by MDS, the aircraft repaired by your directorate. For each aircraft MDS, also provide the number of aircraft scheduled to be repaired in FY 91, the average flow days per individual aircraft, and the primary type(s) of maintenance performed (PDM, mods, etc.).

MDS	No. FY 91	Flow days	Type Maintenance
____________	_____	_____	____________
____________	_____	_____	____________
____________	_____	_____	____________

2. Which of the following terms best describes your directorate's quarterly workload? (check one or use % summing to 100)

_____ Scheduled Maintenance (PDM, mods,etc.) or MISTR Items
_____ Unscheduled Maintenance (Drop-ins) or Job Routed Items
_____ Other (please explain)

3. The total number of employees in your directorate is ________. Of this number, ______ are direct labor and ______ are non-direct labor (including salaried).

4. Your directorate's standard operating week is ______ days per week, and your directorate generally operates ______ shifts per day. (If the operating schedules for various divisions in your directorate differ, please list the schedules for each division on a separate sheet of paper. Also, please indicate whether certain shifts are partially manned.)

5. Is your depot the <u>only</u> provider of depot maintenance for each aircraft MDS listed in question 1? ______ If not, for each MDS, what percentage of the total annual workload do you produce? ____ Please list the outside agencies that perform depot maintenance on these aircraft.

____

____

6. The commodities division at <u>your</u> depot that is the most critical for supporting the repair of the aircraft listed in question 1 is ______________________________

7. The job shop (division or branch-level) at <u>your</u> depot that is the most critical for providing structural repair support (or any repair support besides commodity repair) for the aircraft listed in question 1 is ________________

____

8. For each aircraft listed in question 1, please list the number of Air Force and National Guard operational bases/units (i.e., "customers") that regularly input that type of aircraft to your depot for repair. Also, indicate whether these units are located in the CONUS, the CONUS and overseas, or both the CONUS and overseas. Do you have any regular customers from the Navy, the Marines, the Army, or other organizations? ______ If yes, please note this information at the end of your response to this question.

MDS	No. AF/ Guard Units	Location of Units

PART B: **Command Goals and Depot Objectives**

This section deals with your perception of AFLC's goals and your depot's objectives. Consider goals to be broad results the command intends to accomplish in the long run. Think of objectives as specific, measurable targets that the depot seeks to achieve in the short-term. Goals are general guidelines, while objectives are quantifiable, time-limited targets.

1. List, in order of importance, AFLC's most important goals.

Goal A: ______________________________

Goal B: ______________________________

Goal C: ______________________________

2. Please list, in order of importance, the three most critical objectives of your depot.

First Objective: ______________________________
Second Objective: ______________________________
Third Objective: ______________________________

3. The three most important strategic objectives of your directorate, in order of importance, are:

#1 ______________________________
#2 ______________________________
#3 ______________________________

4. Please circle one number (either 1,2, 3, or 4) on the scale below to indicate the extent to which you believe your depot's and your directorate's objectives support AFLC's goals.

1	2	3	4
No Extent	Slight Extent	Significant Extent	Great Extent

PART C: **Performance Measurement and Competitive Edges**

Performance criteria, commonly known as management indicators, are characteristics used to evaluate functional and system performance. Output per paid manday (OPMD) is a management indicator. Elements critical for system performance may be called competitive edges.

Questions 1 and 2 ask you to rank, in order of importance, six competitive edges that may be considered critical to mission accomplishment. A rank of 1 denotes that the competitive edge is the most critical or important, while a rank of 7 denotes that it is least important. Please use each number (1 through 7) once. Definitions for each element are as follows:

- Cost: Refers to price or to resource saving.
- Quality: Conformance to requirements or fitness for use.
- Lead time: Time required for receipt of component parts.
- Delivery: Ability to meet schedules; due date performance.
- Flexibility: Responsiveness to change, such as changes in production mix or engineering changes.
- Innovation: Origination of useful new practices.

1. In terms of your directorate's objectives, which of the following is the most critical in order for your directorate to accomplish its mission ? (Rank order from 1 to 7)

Cost ______
Quality ______
Lead time ______
Delivery ______
Product/Process Flexibility ______
Product/Process Innovation ______
Other (please explain) ______

2. In terms of your ALC's emphasis on management indicators, which of the following is the most critical in order for your directorate to accomplish its mission? (Rank order from 1 to 7)

Cost ______
Quality ______
Lead time ______
Delivery ______
Product/Process Flexibility ______
Product/Process Innovation ______
Other (please explain) ______

3. How do the current management indicators (performance criteria or measures) aid (or hinder) the directorate's decision-making process?

____
____
____

Does the use of certain management indicators as a basis for decision-making lead to measurable performance improvements in the accomplishment of AFLC goals and depot objectives?
_____ If yes, how can you tell? ____________________
____
____

4. Please list, in order of importance, the top 3 indicators (criteria) used to evaluate your directorate's performance.

#1 ____________________________________
#2 ____________________________________
#3 ____________________________________

5. Please list, in order of importance, the top 3 indicators (criteria) used to evaluate the performance of the divisions that report to you.

#1 ____________________________________
#2 ____________________________________
#3 ____________________________________

6. Please circle one number (either 1, 2, 3, or 4) on the scale below to indicate the extent to which you believe your directorate's management indicators support the objectives of your depot and your directorate and the goals of your command (AFLC).

1	2	3	4
No Extent	Slight Extent	Significant Extent	Great Extent

PART D: **Background Information**

1. Date when completing questionnnaire ____________________

2. Name of directorate and ALC ____________________

3. Person completing questionnaire ____________________

Title ____________________

Commercial Telephone Number ____________________

4. For each of the organizations listed in questions 1, 6, and 7 of part A, please provide a contact for completing a more detailed questionnaire and scheduling an on-site interview. This person should be the division chief/deputy or an individual highly knowledgeable of the division's overall operations.

<u>Aircraft Production</u>
Name and Title: ____________________
Mailing Address: ____________________
Commercial Telephone Number: ____________________

<u>Commodity Division</u>
Name and Title: ____________________
Mailing Address: ____________________
Commercial Telephone: ____________________

<u>Technology and Industrial Division</u>
Name and Title: ____________________
Mailing Address: ____________________
Commercial Telephone: ____________________

DIVISION LEVEL
PRE-VISIT QUESTIONNNAIRE
PERFORMANCE MEASUREMENT STUDY

GENERAL INSTRUCTIONS:

This questionnaire may be completed with either a pencil or a pen. For questions in which "other" or "please explain" is used, please feel free to attach a separate sheet of paper, if needed, to provide a complete answer .

PART A: **Background and General Information**

1. Date when completing questionnaire ____________________
2. Division name and depot location ____________________

____

3. Person completing questionnaire ____________________

   Title ______________________________________

   Commercial Telephone Number ____________________

4. The primary outputs, or reparable items, produced by your division are ______________________________

5. Which of the following best describes your division's quarterly workload? (check one or use % summing to 100)
   _____ Scheduled Maintenance (PDM, mods, etc.) <u>or</u> MISTR Items
   _____ Unscheduled Maintenance (Drop-ins) <u>or</u> Job Routed Items
   _____ Other (please explain) ____________________

6. The total number of employees in your division is ____________ Of this number, ________ are direct labor and ________ are non-direct labor (including salaried).

7. Your division's standard operating week is _____ days per week, and your division operates _____ shifts per day. (If the operating schedules for various branches or sections in your division differ, please list these schedules on a separate sheet of paper.)

PART B: **Command Goals and Depot Objectives**

This section deals with your perception of AFLC's goals and your depot's objectives. Consider goals to be broad results the command intends to accomplish in the long run. Think of objectives as specific, measurable targets that the depot seeks to achieve in the short-term. Goals are general

guidelines, while objectives are quantifiable, time-limited targets.

1. List, in order of importance, AFLC's most important goals.

Goal A: ______________________________
Goal B: ______________________________
Goal C: ______________________________

2. Please list, in order of importance, the three most critical objectives of your depot.

First Objective : ______________________________
Second Objective: ______________________________
Third Objective: ______________________________

3. The three most important strategic objectives of your directorate, in order of importance, are:

#1 ______________________________
#2 ______________________________
#3 ______________________________

4. Please circle one number (either 1, 2, 3, or 4) on the scale below to indicate the extent to which you believe your depot's and your directorate's objectives support AFLC's goals.

1	2	3	4
No Extent	Slight Extent	Significant Extent	Great Extent

PART C: **Performance Measurement and Competitive Edges**

Performance criteria, commonly known as management indicators, are characteristics used to evaluate functional and system performance. Output per paid manday (OPMD) is a management indicator. Elements critical for system performance may be called competitive edges. Questions 1 through 4 concern management indicators used in traditional manufacturing systems. Please indicate beside each indicator, with the appropriate letter, whether the indicator is currently used (U), was previously used (P), is being discussed for future implementation (D), is applicable [but no action is being taken] (A), is not applicable (N/A), or is an indicator with which you are not familiar (DK).

1. Raw Materials and Transformation Performance

a. Raw materials or WIP inventory investment ______
b. Manufacturing cycle time ______
c. Other (please explain) ______

2. Equipment and Facilities Performance
   a. Percentage of down time ______
   b. Capacity utilization percentage ______
   c. Other (please explain) ______

3. Employee Performance
   a. Absenteeism rate ______
   b. Injury frequency rate ______
   c. Productivity index [Earned hours/Clocked hours] ______
   d. Other (please explain) ______

4. End Item Performance
   a. Cost per part ______
   b. Due date performance ______
   c. Amount of rework or scrap generated by order ______
   d. Other (please explain) ______

Questions 5 and 6 ask you to rank, in order of importance, six competitive edges that may be considered critical to mission accomplishment. A rank of 1 denotes that the competitive edge is the most critical or important, while a rank of 7 denotes that it is least important. Please use each number (1 through 7) once. Definitions for each element are as follows:

<u>Cost</u>: Refers to price or to resource saving.
<u>Quality</u>: Conformance to requirements or fitness for use.
<u>Lead time</u>: Time required for receipt of component parts.
<u>Delivery</u>: Ability to meet schedules; due date performance.
<u>Flexibility</u>: Responsiveness to change, such as changes in production mix or engineering changes.
<u>Innovation</u>: Origination of useful new practices.

5. In terms of your division's objectives, which of the following is the most critical in order for your division to accomplish its mission? (Rank order from 1 to 7)

Cost ______
Quality ______
Lead time ______
Delivery ______
Product/Process Innovation ______
Product/Process Flexibility ______
Other (please explain) ______

6. In terms of your directorate's emphasis on management indicators, which of the following is the most critical in order for your division to accomplish its mission? (Rank from 1 to 7)

Cost ______
Quality ______
Lead time ______
Delivery ______
Product/Process Innovation ______
Product/Process Flexibility ______
Other (please explain) ______

7. Please list, in order of importance, the top 3 indicators (criteria) used to evaluate your division's performance.

#1 ______________________________
#2 ______________________________
#3 ______________________________

8. Please list, in order of importance, the top 3 indicators used evaluate the performance of the branches that report to you.

#1 ______________________________
#2 ______________________________
#3 ______________________________

9. Circle one number (either 1, 2, 3, or 4) on the scale below to indicate the extent to which you believe your division's indicators support AFLC's goals and your depot's and directorate's objectives.

1	2	3	4
No Extent	Slight Extent	Significant Extent	Great Extent

PART D: **Barriers to Improving System Performance**

Constraints, or barriers, may prevent your division from achieving its objectives. Questions 1 through 8 relate to elements of various systems that might act as constraints to overall system performance. Indicate beside each element, with the appropriate letter, whether it is <u>routinely</u> used (<u>U</u>), being implemented (<u>I</u>), being discussed for future implementation (<u>D</u>), is applicable [but no action is being taken](<u>A</u>), or is not applicable (<u>N/A</u>). If you are unfamiliar with the element, mark <u>DK</u> for "Do Not Know".

1. Inventory Management
   a. ABC Analysis ______
   b. Inventory Cycle Counting ______

2. Material Requirements Planning System (MRP) ______

3. Manufacturing Resource Planning System (MRP II) ______

4. Just-in-Time System (JIT) ______

5. Project Management System (such as PERT or CPM) ______

6. Drum-Buffer-Rope (DBR) ______

7. Engineering Activities
   a. Computer-aided Manufacturing (CAM) ______
   b. Computer-aided Design (CAD) ______

8. Total Quality Management
   a. Statistical Process Control ______
   b. Quality Improvement Teams (such as PATs) ______
   c. Other (please explain) ______________________________

9. For each of the types of constraints listed below, fill in the blank with an example of that constraint at your depot.

Market [internal capacity/capability exceeds customer demand]

____

Material [shortages due to unreliable vendors or misallocation]

____

Capacity [of resources is insufficient to meet workload]

____

Logistical [Production/inventory control, MIS & data systems]

____

Managerial [Local and DOD management policies and procedures]

____

Behavioral ["cherry picking" and "keep busy" attitudes]

____

10. If you could eliminate one specific constraint, or barrier, to mission accomplishment in your division, what would it be?

____

Performance Measurement and Competitive Edges at Branch Level

Performance criteria, commonly known as management indicators, are characteristics used to evaluate functional and system performance. Output per paid manday (OPMD) is a management indicator. Elements critical for system performance may be called competitive edges. Questions 1 and 2 ask you to rank, in order of importance, six competitive edges that may be considered critical to mission accomplishment. A rank of 1 denotes the most critical competitive edge, while a rank of 7 denotes the least important element. Please use each number (1 through 7) once. The elements are defined as follows:

- Cost: Refers to price or to resource saving.
- Quality: Conformance to requirements or fitness for use.
- Lead time: Time required for receipt of component parts.
- Delivery: Ability to meet schedules; due date performance.
- Flexibility: Responsiveness to change, such as changes in production mix or engineering changes.
- Innovation: Origination of useful new practices.

1. In terms of your branch's objectives, which of the following is the most critical in order for your branch to accomplish its mission? (Rank order from 1 to 7)

Cost	______
Quality	______
Lead time	______
Delivery	______
Product/Process Innovation	______
Product/Process Flexibility	______
Other (please explain)	______

2. In terms of your division's emphasis on management indicators, which of the following is the most critical in order for your branch to accomplish its mission? (Rank order from 1 to 7)

Cost	______
Quality	______
Lead time	______
Delivery	______
Product/Process Innovation	______
Product/Process Flexibility	______
Other (please explain)	______

3. Please list, in order of importance, the top 3 indicators (criteria) used to evaluate your branch's performance.

#1 ______________________________

#2 ______________________________

#3 ______________________________

4. Please list, in order of importance, the top 3 indicators (criteria) used to evaluate the performance of the sections that report to you.

#1 ______________________________

#2 ______________________________

#3 ______________________________

5. Please circle one number (either 1, 2, 3, or 4) on the scale below to indicate the extent to which you believe your branch's management indicators support the objectives of your depot and your directorate and the goals of your command (AFLC).

1	2	3	4
No Extent	Slight Extent	Significant Extent	Great Extent

Background Information

Your Name and Job Title ______________________________

Branch Name and Office Symbol ______________________________

Commercial Telephone ______________________________

Performance Measurement and Competitive Edges at First-line Level

Performance criteria, commonly known as management indicators, are characteristics used to evaluate functional and system performance. Output per paid manday (OPMD) is a management indicator. Elements critical for system performance may be called competitive edges. Questions 1 and 2 ask you to rank, in order of importance, six competitive edges that may be considered critical to mission accomplishment. A rank of 1 denotes the most critical competitive edge, while a rank of 7 denotes the least important element. Please use each number (1 through 7) once. The elements are defined as follows:

- Cost: Refers to price or to resource saving.
- Quality: Conformance to requirements or fitness for use.
- Lead time: Time required for receipt of component parts.
- Delivery: Ability to meet schedules; due date performance.
- Flexibility: Responsiveness to change, such as changes in production mix or engineering changes.
- Innovation: Origination of useful new practices.

1. In terms of your branch's objectives, which of the following is the most critical in order for your branch to accomplish its mission? (Rank order from 1 to 7)

Cost	______
Quality	______
Lead time	______
Delivery	______
Product/Process Innovation	______
Product/Process Flexibility	______
Other (please explain)	______

2. In terms of your division's emphasis on management indicators, which of the following is the most critical in order for your branch to accomplish its mission? (Rank order from 1 to 7)

Cost	______
Quality	______
Lead time	______
Delivery	______
Product/Process Innovation	______
Product/Process Flexibility	______
Other (please explain)	______

3. Please list, in order of importance, the top 3 indicators (criteria) used to evaluate your <u>own</u> performance.

#1 ____________________
#2 ____________________
#3 ____________________

4. Please list, in order of importance, the top 3 indicators (criteria) used to evaluate the performance of the workers that report to you.

#1 ____________________
#2 ____________________
#3 ____________________

5. Please circle one number (either 1, 2, 3, or 4) on the scale below to indicate the extent to which you believe your branch's management indicators support the objectives of your depot and your directorate and the goals of your command (AFLC).

1	2	3	4
No Extent	Slight Extent	Significant Extent	Great Extent

Background Information

Your Name and Job Title ____________________

Branch Name and Office Symbol ____________________

Commercial Telephone ____________________

PERFORMANCE MEASUREMENT STUDY
ON SITE INTERVIEW SCHEDULE
DIRECTORATE/DIVISION/BRANCH LEVEL

PART A: Goals and General Information

1. Does the division/branch have stated goals, objectives, and/or a mission statement that is shared with all employees?
    a. How was it developed?
    b. How does it relate to the objectives or mission of the directorate?
    c. What is the evidence in support of such a statement?

2. Describe your organizational structure.
    a. Number and name of branches?
    b. How are they structured and supervised?
    c. What are the reporting relationships across branches?
    d. How has the reorganization made your job easier? How has it made it more difficult?
    e. Sample organizational chart (if possible)

3. Who are your internal customers? Who are your external customers? Describe the interaction between your division/branch and other divisions/branches in this directorate and other directorates at this ALC or other ALCs or depots (internal customers). Describe your relationship with the operational units you support (external customers).

4. Describe the general product flows from raw material or disassembled end item to finished product or reassembled end item.
    a. What are the major operations involved in the repair or transformation process?
    b. In V-A-T terminology, does the flow correspond to a "V", an "A", or a "T" plant? Or is it a combination of these?

5. Describe the techniques your division/branch uses to monitor cost (total cost analysis, comparison of actual vs. budgeted cost, cost trend analysis) and how cost accounting information is used.
    a. Functional reporting?
    b. Expenditure justification?
    c. Inventory valuation? (Raw materials, WIP, Finished goods)
    d. Allocation of overhead?
    e. Performance measurement?

PART B: **Competitive Edges**

Refer to the pre-visit survey and ensure that individuals surveyed understood all definitions and how to rank the elements. Also ensure that individuals surveyed listed the three most important performance criteria used to evaluate their unit's performance and the performance of the sections that report to them.

1. On the basis of unit objectives, what is your most critical competitive edge for mission accomplishment? For evaluating your branches or sections?

2. On the basis of unit criteria, what is your most critical competitive edge for mission accomplishment? For evaluating your branches or sections?

3. Are there other competitive edges not listed?

4. In order of importance, what are the top three indicators used to evaluate the performance of your unit?

5. In order of importance, what are the top three indicators you use to evaluate the performance of the sections that report to you?

PART C: **Performance Measurement**

1. Compare and contrast the management indicators reported to your directorate and your depot with the indicators you use to evaluate the performance of your branch chiefs and first-line supervisors.
   a. Of the indicators reported to higher levels, which three are of most concern to your director? The ALC commander?
   b. Are the indicators you use to measure the performance of your supervisors the same ones by which they perceive their performance to be evaluated?
   c. What are the indicators related to utilization of labor, machines, materials, and/or facilities and to capacity?
   d. Are there time-related indicators? What are they?
   e. At which points in the production process are performance data collected? Why were these points selected?
   f. What is the frequency of recording and gathering such data?
   g. Is there a focus on trends and continuous improvement? What indicators are used to judge long-term performance?

2. Describe the procedures used to monitor discrepancies between actual performance and standards, such as exception reporting. What is the management process for review and follow-up?
   a. Is a formal procedure used for reviewing and changing the content of critical reports and exception messages? If yes, how frequently are such reports reviewed and updated?
   b. Do users make decisions based on the system's reports?
   c. Does the content of reports exceed job requirements?
   d. Is the report information too outdated to be of any value?

3. How is the information from the performance measurement system used?
   a. For performance control?
   b. As a performance goal?
   c. As standards for ongoing performance improvement?
   d. For compensation or incentive decisions (reward system)?
   e. For competition among directorates or depots?
   f. Shared with employees higher or lower in the command chain and/or across divisions or branches within the directorate?

4. Compare the management indicators presented in the ALC Management Review with those presented in the past (2-5 years ago).
   a. What are the specific changes? Why were they made?
   b. Are there different indicators? If so, what are they?
   c. Are different items reported? If so, what are they?
   d. Have the reporting units or time periods changed? How?
   e. Have the indicators become more or less cost-related?
   f. Have the indicators become more or less time-related?
   g. How was the performance measurement system change implemented?

5. What performance information is reported to AFLC?
   a. Have command reporting requirements changed in the last few years or months? If yes, how have they changed?
   b. What indicators are of most concern to AFLC headquarters?

6. How does the use of efficiency indicators, such as labor effectiveness and output per paid manday (OPMD), affect the ability of your division/branch to achieve objectives related to customer satisfaction, on-time delivery, quality products, and production cost reduction/minimization?
   a. What is the impact on quality, inventory levels, operating expenses, and delivery performance?
   b. How are these indicators "gamed"?
   c. Are different indicators used for different types of work (MISTR vs PDM, etc.)?

7. How does the use of flow days, AMREP due dates, customer service levels, or any other due date performance indicators help or hinder the achievement of on-time delivery objectives?
   a. How does the use of these indicators impact other areas besides delivery performance?
   b. How are these indicators "gamed"?

8. What procedures are used in quality management and quality control? Where and how are these procedures used?
   a. Fishbone diagrams (cause-effect analysis)?
   b. Pareto analysis?
   c. Statistical process control (SPC)?
   d. Quality at the source (pokayoke, self-inspection)?
   e. Taguchi methods (orthogonal arrays, quality loss)?
   f. Control charts, such as R-charts, p-charts, and X-charts?
   g. Acceptance sampling and/or vendor certification programs?
   h. Quality audits?
   i. Other?

9. If SPC is used, on what operations is it employed? How were these operations selected for SPC monitoring? What is measured at these operations? Are the results tracked over time and posted?

10. Describe how the status of TQM training and TQM projects is reported to higher levels.
   a. What verification is there that benefits materialize to the bottom line?
   b. How are benefits quantified?

11. In what areas is engineering performance evaluated/reported?
   a. Engineering changes?
   b. First article approvals?
   c. Modification/development schedules and milestone deadlines?
   d. Product/process innovation?
   e. Product/process flexibility?
   f. Other?

12. What are the specific plans and priorities for future actions regarding performance measurement systems in this division/branch?
   a. What indicators do you believe are needed to support the goals and objectives of your division/branch, your directorate, your depot, and AFLC?
   b. What indicators do you foresee five years from now?
   c. Has there been any discussion concerning the use of throughput (T), inventory (I), and operating expense (OE) indicators to measure division or directorate performance?
   d. In your opinion, what is the ultimate performance measurement system for the depot maintenance environment?

PART D: **Barriers to Improving System Performance**

Physical

1. Describe any aspects of the present layout which may be inhibiting product flow and/or mission accomplishment. If problems exist, what is being done to remedy them?
   a. Have product network flows been correctly analyzed (VAT)?
   b. Do you have sufficient space and/or facilities?
   c. Is obtaining funding for improvements a problem?

Managerial

2. Discuss how personnel policies impact your operations.
   a. How has the freeze on hiring and promotions affected your ability to accomplish your mission?
   b. How do union policies impact division/branch performance?
   c. How flexible is your workforce? Do you cross-train your workers?
   d. Are any JIT-type performance measures, such as number of jobs mastered, number of job classifications, and number of suggestions, used to evaluate worker performance?

3. Discuss how DOD and AFLC procurement/contracting policies impact your mission accomplishment. What is the impact of:
   a. Sole sourcing and other competition advocacy issues?
   b. Bidding by outside vendors against the ALCs?
   c. Small business requirements?
   d. Stock funding of depot level reparables?
   e. OSD/OMB directed inflation rates?
   f. Stabilized prices?
   g. Funding delays and reductions?
   h. Zero profit/loss goals?
   i. Long lead times for contract awards?
   j. Other policies and problems?

4. What changes in local and DOD policies and procedures could be implemented to speed the processing of customer orders and improve system performance in your division/branch? Could or should policies be changed regarding:

   a. Workload negotiations and work induction?
   b. Requirements computations and projections?
   c. Pipeline flow between depot and operational units?

5. Provide a specific example of how one particular policy has negatively impacted cost, quality, lead time, delivery (schedule), product/process innovation and/or product/process flexibility in your division/branch or directorate.

Logistical

6. Describe the management information and data systems used by this division/branch.

   a. How do they enhance or impede mission accomplishment? How do they constrain various processes, particularly the repair negotiations/maintenance workloading process?
   b. Do you have problems with information lag? Lack of system flexibility? Data stratification?
   c. What plans exist for MIS simplification and integration?
   d. How will the implementation of DMMIS affect your operation?
   e. What are the potential benefits and possible drawbacks of DRIVE?
   f. Are any other additional systems applicable to depot maintenance being planned locally or by AFLC?

7. Discuss your inventory management policies and procedures.

   a. Has an ABC analysis been performed? If yes, what criteria are used to classify inventory categories?
   b. Is cycle counting used to measure the accuracy of inventory records? If yes, how often is it done? If no, how often are physical or wall-to-wall inventories conducted?
   c. Are all inventory items identified by the use of a shop order or inventory labeling system? Do inventory items have unique part numbers?
   d. What is your stocking policy? Is safety stock utilized? If yes, discuss where and how it is used (in finished goods, for spare parts, etc.)
   e. Are locked stockrooms used to secure inventory? How are open bench stock items controlled?
   f. What kind of lot sizing rules are used for making decisions related to the release of inventory to the

shop floor and the ordering of replacement parts and raw material?

g. Estimate the accuracy of your inventory records and describe any problems encountered with records accuracy.

h. Describe what criteria, such as inventory turns, number of stockouts, etc., are used to assess inventory management.

i. Explain how DOD and AFLC policies impact inventory management and inventory levels for raw materials, WIP, and finished goods.

8. Discuss your planning, scheduling, and production control procedures.

a. How do you forecast requirements for component parts and bits and pieces used to repair end items?

b. Is the monthly/weekly capacity of the bottleneck work center used as an estimate of production capacity?

c. What techniques are used, particularly at the bottleneck work center, to manage queues? Is operation splitting or overlapping used? Is drum-buffer-rope used?

d. Is a formal master production schedule used? If yes, describe it. Planning horizon? Fences? Level schedule?

e. Is a daily dispatch list used to maintain order priorities? Is the backlog at the bottleneck work center controlled by a daily dispatching technique that considers available work center capacity?

f. Do you know which parts typically appear on the "hot" list?

g. Is the amount of expediting and overtime monitored and reported? If yes, describe the procedures used.

h. How are standards for repair processes/operations established? How often are they updated? What are the AFLC regulations and local policies concerning standards development and revision? Bills of material? Routings?

i. How often are bills of material and routings updated? What problems exist with their accuracy and validity?

j. Differentiate the job responsibilities for preplanners, planners, schedulers, and production controllers in your division/branch. How much system visibility do individuals in each of these four areas possess?

9. Discuss what has been done to streamline the technical complexity of your repair processes so that customers receive quality products in a timely manner.

a. Have the magnitude and frequency of engineering changes been reduced?

b. What has been done to speed up first article approval?
c. Do you employ alternate routings? If yes, give examples of where such routings are used.
d. To what degree are your parts standardized? Do you have standard product designs?
e. What has been done regarding product/process innovation? What factors inhibit implementing such innovations?
f. How closely do your engineers work with line personnel?

<u>Overall</u>

10. If you could eliminate one specific constraint in your division or branch, what would it be? How would you implement the changes necessary to eliminate this constraint? What do personnel in each of the following functional areas see as <u>their</u> biggest constraint?

a. Planning and scheduling?
b. Production and inventory control?
c. Quality management?
d. Facilities and product engineering?
[talk to personnel in each of the above functional areas]

PART E: **Background Information**

Date ________________ Depot Location ________________

Division/Branch Name ______________________________

Primary Reparable Item(s) __________________________

____

Name and Job Title of Interviewee ____________________

____

Commercial Telephone _______________________________

Additional Comments:

PERFORMANCE MEASUREMENT STUDY
ON SITE INTERVIEW SCHEDULE
GENERAL QUESTIONS
DIRECTORATE/DIVISION/BRANCH LEVEL

PART A: **Goals and General Information**

1. Does the division/branch have stated goals, objectives, and/or a mission statement that is shared with all employees?

2. Describe your organizational structure.

3. Who are your internal customers? Who are your external customers? Describe the interaction between your division/branch and other divisions/branches in this directorate and other directorates at this ALC or other ALCs or depots (internal customers). Describe your relationship with the operational units you support (external customers).

4. Describe the general product flows from raw material or disassembled end item to finished product or reassembled end item.

5. Describe the techniques your division/branch uses to monitor cost (total cost analysis, comparison of actual vs. budgeted cost, cost trend analysis) and how cost accounting information is used.

PART B: **Competitive Edges**

Refer to pre-visit survey and ensure that individuals surveyed understood all definitions and how to rank the elements.

PART C: **Performance Measurement**

1. Compare and contrast the management indicators reported to your directorate and your depot with the indicators you use to evaluate the performance of your branch chiefs and first-line supervisors.

2. Describe the procedures used to monitor discrepancies between actual performance and standards, such as exception reporting. What is the management process for review and follow-up?

3. How is the information from the performance measurement system used?

4. Compare the management indicators currently presented to the center commander in the ALC Management Review briefing with those presented in the past (2-5 years ago).

5. What performance information is reported to AFLC?

6. How does the use of efficiency indicators, such as labor effectiveness, affect the ability of your division/branch to achieve objectives related to customer satisfaction, on-time delivery, quality products, and production cost reduction?

7. How does the use of flow days, AMREP due dates, customer service levels, or any other due date performance indicators help or hinder the achievement of on-time delivery objectives?

8. What procedures are used in quality management and quality control? Where and how are these procedures used?

9. If SPC is used, on what operations is it employed? How were these operations selected for SPC monitoring? What is measured at these operations? Are the results tracked over time and posted?

10. Describe how the status of TQM training and TQM projects is reported to higher levels.

11. In what areas is engineering performance reported/evaluated?

12. What are the specific plans and priorities for future actions regarding performance measurement systems in this division/branch?

PART D: **Barriers to Improving System Performance**

1. Describe any aspects of the present layout which may be inhibiting product flow and/or mission accomplishment. If problems exist, what is being done to correct them?

2. Discuss how personnel policies impact your operations.

3. Discuss how DOD and AFLC procurement/contracting policies impact your mission accomplishment.

4. What changes in local and DOD policies and procedures could be implemented to speed the processing of customer orders and improve system performance in your division/branch?

5. Provide a specific example of how one particular policy has negatively impacted cost, quality, lead time, delivery (schedule), product/process innovation, and/or product/process flexibility in your division/branch or directorate.

6. Describe the management information and data systems used by this division/branch.

7. Discuss your inventory management policies and procedures.

8. Discuss your planning, scheduling, and production control procedures.

9. Discuss what has been done to streamline the complexity of your repair processes so that customers receive quality products in a timely manner.

10. If you could eliminate one specific constraint in your division or branch, what would it be? How would you implement the changes necessary to eliminate this constraint?